COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR 2017

HEARINGS

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

SUBCOMMITTEE ON COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES

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PART 5

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COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR 2017

TUESDAY, FEBRUARY 23, 2016.

DEPARTMENT OF COMMERCE

WITNESS

HON. PENNY PRITZKER, SECRETARY, DEPARTMENT OF COMMERCE

Mr. CULBERSON. The first hearing of the Commerce, Justice, Science Appropriations Subcommittee will come to order. It is a privilege to have with us today the Secretary of Commerce, Penny Pritzker.

We have begun our work expeditiously this year. Chairman Rogers has tasked us and each subcommittee to get started early to get our work done as quickly as possible because we have a budget agreement and a favorable forecast for the Senate, we hope, Mr. Chairman to get all 12 appropriations bills done separately, and hope that they will come not only to the floor of the House separately, but to the floor of the Senate separately, and we hope at the end of the year separately be considered by the Congress.

And in keeping with that task, Mr. Chairman, and to keep our schedule moving quickly, we are going to follow the 5-minute rule for questions, and I certainly will not cut anybody off mid-sentence. I will recognize members in order of seniority based on who is present at the beginning of the hearing, and going back and forth, of course, between parties. For late comers, I will recognize those members in the order that you arrive, and continue to go back and forth between the parties until all members are recognized.

And this subcommittee, in particular, has a long history. As you know, Chairman Rogers has told me many times, this is one of your favorite subcommittees. The jurisdiction of this subcommittee encompasses so many good things that we do in helping keep the American people safe, and enforcing our laws, and ensuring that the nation's trade—as the Secretary of Commerce will talk to us about here in a minute—looking after the nation's farmers and workers with the NOAA satellites. We also, of course, have jurisdiction over NASA and the National Science Foundation.

About everywhere you look, the work of this subcommittee is just pure good, and it is one that is a real privilege for me to chair. It is the one committee I truly wanted to chair when I came on Appropriations, and I thank you for the trust you have invested in me, Chairman Rogers, it is a real privilege. And we are delighted to start with you today, Madam Secretary. It is a privilege to have

a chance for you to talk to us about the President's 2017 Department of Commerce Budget request.

And as we all know, the Department of Commerce has a number of important functions including the administration of America's patent and trademark laws; preparing for and conducting the Decennial Census; enforcing our trade laws; forecasting the weather; managing our fisheries; and protecting and exploring our oceans; and mapping and cataloging the immense mineral wealth that lies beneath the ocean under America's exclusive economic zone, which, in fact, encompasses about—if you look at the entire EEZ, it is about 50 percent of America lies under the nation's oceans, and there is vast mineral wealth out there, and that is a key part of your responsibility, Madam Secretary.

Now, we on the committee—I know many of the members here share my concern that the budget request you have submitted to us includes nearly a half-billion-dollars in discretionary spending increases, and more than $2 billion in new mandatory spending. Frankly, they are just gimmicks. Including such things as a $10 barrel tax on oil, which is not likely to happen.

So it is important that we focus on the realities that we will actually be able to handle this year in our tight budget environment, and recognize that we are simply not going to be raising taxes on the American people. And so to that extent, the President's budget request is not realistic, and that also makes our job on this committee more difficult. But we do appreciate the work that you do, Madam Secretary, have a duty to our constituents to ensure that their hard-earned tax dollars are spent wisely, and we will make certain that those tax dollars are spent to enforce the law as written by Congress.

We will also be focusing, in particular, in our hearing today about making sure that we are protecting the Internet from foreign governments; ensuring that the 2020 census is going to cost less than the census that was conducted in 2010. We want to make certain, Madam Secretary, that the weather satellite program meets their cost and schedule timelines. And something of particular interest to me and to my predecessor, Frank Wolf, we want to make sure that we are strengthening cyber and information technology security at the Department of Commerce.

But before we proceed, I would like to recognize my colleague and good friend, Mr. Honda, for any remarks that he would like to make.

Mr. HONDA. Thank you, Mr. Chairman.

As we start the FY 17 process, let me start by saying how grateful I am for my chairman's leadership last year and how I look forward to working with him and my colleagues on this committee to build upon last year's successes and craft a strong CJS appropriation—one that promotes strong economic growth, robust innovation, and societal equity.

Welcome, Madam Secretary, and thank you for testifying today, and thank you for your commitment to smart, effective Federal investments in business and innovation.

I think it is fitting that my first hearing as ranking member of this subcommittee is with the Secretary of Commerce. My district is Silicon Valley in California.

It is a region known for its strong, innovative, high-tech economy that has reshaped the world we live in, and it is also a region that is dealing with the challenges and inequity that accompany the great opportunities of our 21st century economy. And I am pleased that the President's budget includes robust support for our nation's priorities to promote new era manufacturing, which I am sure you are very interested in; investment in American companies; and quality data that our government's businesses and researchers rely upon, as we know.

As we prepare our market to be a leader in today's global data-driven economy, we must ensure that our investments and programs lift up all Americans across this nation, and reach those who have been historically left behind. As we grow public/private partnerships to invest in advanced manufacturing, we must also grow partnerships to invest in our minority youth entrepreneurs.

As we ensure that we accurately and cost effectively count each and every American, we must especially ensure that we count all of our small, immigrant and rural populations as well as those in the territories. A strong American economy is one that is felt by all, and I believe that the President's budget does just that.

So thank you again for joining us this morning, Madam Secretary, and I look forward to hearing your responses to questions asked by my chairman and my colleagues here today.

Mr. CULBERSON. Thank you, Mr. Honda. It is my privilege to recognize the chairman of the full committee, the gentleman from Kentucky, Mr. Rogers.

The CHAIRMAN. Thank you, Mr. Chairman. You do a great job here, by the way.

Mr. CULBERSON. Thank you.

The CHAIRMAN. Madam Secretary, thank you for being with us. We appreciate your taking the time to justify your budget request.

As you know, last year we all reached an agreement setting discretionary caps for both 2016 and 2017. I am proud that we crafted an omnibus bill for 2016, that adhered to the terms of that bipartisan agreement. It's not always easy to live within your means, but it is necessary and responsible. That is why I am disappointed that the President has chosen to put forth a budget request for your department that is filled with gimmicks in order to side skirt the very same budget caps that he signed into law last year.

The budget you have put before us requests $2 billion in new mandatory funding, making this budget effectively DOA. I mean, we owe over $19 trillion, growing like a weed, but we only appropriate a little less than one-third of Federal spending. Federal spending is going to be $400 trillion; we only appropriate $100 trillion of that.

When I came here, we appropriated two-thirds, now it is one-third. In the last 5 years, in an effort to get at the spending problem that we have, we have cut discretionary spending by almost $200 billion over the last 5 years, and that is an achievement, big time. But, in the meantime, the mandatory spending has grown like a weed and the public is alarmed, frightened, scared, frustrated, mad. And yet here you come with a $2 billion increase in mandatory funding as if you didn't know that would make me mad.

For fiscal 2017, you have requested $9.73 billion in discretionary; that is a 5 percent increase over the previous year. That number proposes increases for nearly every agency, every program at your department. Given current law under the bipartisan budget agreement, that is unrealistic, to say the very least.

It is the job of this committee to ensure that the programs that serve taxpayers well, are funded responsibly. Innovation and job creation are essential to growing the national, regional, and State economies, and despite this unrealistic budget submission, your agency does do a lot of great work, including in my home State of Kentucky.

Over the last 7 years, we have been hit with the war on coal; the loss of over 10,000 coal jobs in my district alone. That is just coal jobs, that does not mention convenience stores, and truck drivers, and grocery stores, and restaurants, and the like.

We are in a depression in my part of the world. They shuttered the AK Steel plant in Ashland. Regions like Appalachia—and we are not alone—that have been forced to try to diversify their economies as a result of the hostile regulatory environment of this administration and emerging energy technologies and have had to think creatively and strategically about what we do next to live.

From the grassroots level, I have worked with our outgoing governor, Governor Beshear, and now the new governor, Bevin, on a regional community development initiative that we have dubbed SOAR, Shaping Our Appalachian Region. It is an effort to try to diversify the economy, to bring new ways to create jobs to replace those we lost.

Last summer, your assistant secretary for economic development, Jay Williams, came down to our area to address the second annual SOAR summit conference; almost 2,000 people. During his remarks, he shared lessons learned from serving as the Mayor of Youngstown, Ohio, and explained how our communities can leverage Economic Development Administration resources to help create those jobs and opportunities that we desperately need for new businesses across the Appalachian region. And I deeply appreciated the time he has spent with us, two years in a row, frankly.

As he mentioned, Commerce has many programs that have helped, and continue to help, these struggling coal mining communities. For fiscal 2017, the President's budget proposes to continue to fund what he calls the Power Plus Program, but does not include a specific funding amount, or propose to continue funding the Assistance to Coal Communities program within EDA. That is despite the fact that Congress has included clear direction in the last three omnibus bills to support coal communities.

I would be remiss if I did not mention—even though it is outside your purview—that I continue to believe that Power Plus is toothless without regulatory relief for these coal mining communities. The war on coal continues. I look forward to hearing your plan for those important programs in the future.

Additionally, the U.S. steel market has been flooded by cheap imports from around the world; they are dumping steel on us. That illegal dumping of steel in America has put many of the U.S. steel makers in jeopardy, like AK Steel in Ashland which is going to close. Across the country, steel companies are closing facilities and

sending their employees home. The President's budget requests an increase for the International Trade Administration, but only a small portion is targeted toward enforcement and compliance.

With this continuous increasing pressure on U.S. steel companies, I am very troubled by the allocation of the requested budget increase. I would like to hear about how you plan to address the unfair policies that countries like China are today pursuing to the detriment and death, frankly, of U.S. manufacturers in this country and their workers.

We have many challenges ahead of us, I look forward to working with you throughout the process. Thank you for joining us, we wish you well. I yield.

Mr. CULBERSON. Madam Secretary, we appreciate your testimony today, and the written statement that you have will be entered into the record. And I would ask, if you could, to please keep your opening statement to 5 minutes so we will have additional time for questions.

DEPARTMENT OF COMMERCE FISCAL YEAR 2017 BUDGET REQUEST

Secretary PRITZKER. Absolutely. First of all, Chairman Rogers, Chairman Culberson, Ranking Member Honda, and the Members of the Subcommittee, thank you for the opportunity to lay out the priorities for the President Obama's fiscal year 2017 budget request for the Department of Commerce.

Building on your strong support over the last 3 years, this request will enable the Department of Commerce to serve as an effective voice for business in the Federal Government; continue our work with the private sector on policy development; and help firms of all sizes enter new markets.

Our fiscal year 2017 budget request provides $9.7 billion in discretionary funding to support our core priorities under our open-for-business agenda, while also allowing us to make our department more efficient.

This agenda is focused on four key priorities—promoting trade and investment; spurring innovation and entrepreneurship; gathering and acting on environmental intelligence; and fueling a data-driven economy. Today I want to highlight just a few key initiatives under each of these areas.

First, the budget request will enable our department to better serve American businesses as they seek to access the 96 percent of potential customers who live beyond our borders. Increasing trade and investment is critical to growing our economy. Nearly 10 million U.S. jobs are supported by exports.

This budget request will allow us to expand the footprint of our foreign trade specialists to help American companies navigate exporting into new markets. It will strengthen our team's ability to enforce trade laws that protect U.S. industries from unfair trade practices, and ensure foreign governments' compliance with the international trade agreements. We are also requesting funding to expand Select USA, the first ever whole of government effort to facilitate business investment to and within the United States.

Second, the budget request will also increase investment in the National Network for Manufacturing Innovation, which was established to ensure America's global leadership in manufacturing.

Each institute has a unique focus, but a common goal: to create, showcase, and bring new made-in-America capabilities in manufacturing processes from lab to market in the near term. The Department of Commerce oversees the network of the seven existing institutes, and we have the unique authority to establish new institutes in technologies areas selected by industry.

Another key piece of our agenda is ensuring that communities and businesses have the information they need to prosper in a changing environment. This budget request supports the National Oceanic and Atmospheric Administration's core missions that promote more resilient communities, including fostering healthy marine resources, and improving forecasting accuracy, and lead times for severe weather.

To ensure NOAA retains a robust observational infrastructure, the budget also provides $2.3 billion to fully fund the next generation of weather and environmental satellites, including the Polar Follow On Satellite Program.

Finally, recognizing that data powers the 21st century economy, the census bureau is committed to achieving a 2020 census that is both accurate and efficient, with the goal of keeping the per household cost below that of the 2010 Decennial Census.

Investing wisely now in preparation for the 2020 census will potentially save American taxpayers more than $5 billion. To achieve these savings, this request provides a $1.6 billion to develop, test, and implement the innovative design methods.

The fiscal year 2017 budget request furthers priority programs that have a strong return on investment for American taxpayers. Ultimately, these priorities are only a small piece of the Commerce department's work to develop and implement policies that support economic growth, enhance our country's competitiveness, and strengthen America's businesses both at home and abroad.

I look forward to answering your questions today, and thank you for having me.

[The information follows:]

WRITTEN TESTIMONY BY SECRETARY PENNY PRITZKER
U.S. DEPARTMENT OF COMMERCE
FISCAL YEAR 2017 BUDGET REQUEST

Chairman Culberson, Ranking Member Honda, and members of the Subcommittee, thank you for this opportunity to discuss President Obama's Fiscal Year 2017 (FY17) Budget Request for the U.S. Department of Commerce. The priorities included in the FY17 Budget request build upon the important investments you enacted in FY16 and I am grateful for your support.

As the Secretary of the Commerce, it is my responsibility to ensure that the Department's resources are allocated to the highest priority programs and projects that provide the largest benefits for businesses, communities, and workers across the United States. With the $9.7 billion in discretionary funding requested for Commerce in the FY17 Budget, I believe we can make significant progress in all of our key mission areas that we carry out on behalf of the American people.

I'm proud that my Department has played such an integral role in creating 14 million jobs and helping to set the Nation on a fiscally responsible course, but I am cognizant of the immense challenges that remain in front of us. The funding in the FY17 Budget is designed to address those challenges by making critical investments in the following key areas: promoting exports and foreign investment; increasing research and development opportunities to foster technological innovations and the digital economy; strengthening entrepreneurship and the U.S. economy; fueling a data-driven economy; and supporting the environment and natural resources.

At the same time, the FY17 Budget also reflects the difficult tradeoffs that were made to capitalize on ways to operate more efficiently and reduce costs.

Our FY17 Budget request directly aligns with the Department's "Open for Business" Agenda, which reflects Commerce's unique role as the voice of business and the Administration's focus on economic growth and job creation. Through the "Open for Business" Agenda, successful initiatives have been launched to help American businesses prosper in foreign markets, improve market access to make sure American companies are on equal footing when competing abroad, and leverage public-private partnerships to enable businesses and communities to make better use of government data.

None of our achievements would be possible without the support of the Congress and especially the members of this Committee. I look forward to working with you so that we can continue to build on our economic momentum and accelerate our growth both in the United States and around the world.

Outlined below in greater detail are specific investments that we have prioritized in the FY17 Department of Commerce Budget:

Promoting Trade and Investment:

The United States is the world's largest exporter and importer of goods and services, and the world's largest recipient of foreign direct investment. Increasing trade and investment is critical to growing our economy as nearly 10 million U.S. jobs are now supported by exports. In 2015, the United States exported $2.23 trillion in goods and services and our exports are flourishing in worldwide markets from China to Brazil to Mexico.

The FY17 President's Budget requests $521 million for the International Trade Administration (ITA), which is nearly an 8 percent increase over the FY 2016 enacted amount. This funding level will allow ITA to expand the presence of its foreign trade specialists, both overseas and domestically, as well as strengthen ITA's trade enforcement team.

Within its topline, the Budget includes $20 million for ITA to expand SelectUSA, which seeks to recruit foreign businesses to invest and create new jobs in the United States. Moreover, the Department of Commerce will serve as the host for the Select USA Investment Summit, an annual event that attracts thousands of international and national leaders from businesses, economic development organizations, government, and other industry stakeholders. This year's Summit is scheduled for June 19-21 in Washington, DC.

Other funds will support ITA's efforts to make it easier for U.S. companies of all sizes to reach consumers who live beyond our borders. ITA is educating companies about markets opened by Free Trade Agreements and working with industries so they can overcome obstacles in foreign markets and take advantage of export financing options. At the same time, this budget will support ITA's efforts to vigorously enforce our trade laws, and protect American jobs by ensuring a level playing field for American companies.

The President's Budget also provides $127 million for the Bureau of Industry and Security (BIS), a $14 million increase over the FY 2016 enacted level. These resources will augment BIS' ongoing domestic and international efforts to curtail illegal exports while facilitating secure trade with U.S. allies and close partners. The FY17 request enables BIS to proactively engage with U.S. industries and foreign governments and companies and help them better understand and comply with complex regulations that govern U.S. trade and enforcement policies (such as the Export Administration Regulations).

Spurring Innovation and Technology:

The Budget increases investment in some of the Department's most effective programs to spur innovation and economic growth in the manufacturing sector.

Launched in 2012, the Federal government spearheaded a national effort to create public-private institutes focused on manufacturing innovation. The National Network for Manufacturing Innovation (NNMI) was established as a way to accelerate development and adoption of cutting-edge manufacturing technologies for new products that can compete in international markets. Each NNMI has a unique focus, but a common goal to create, showcase, and deploy new capabilities and new manufacturing processes.

The $1 billion request in the Budget for the National Institute of Standards and Technology (NIST) builds on this initiative. Specifically, $42 million is provided to sustain the first Commerce-led institute and launch two new institutes (in total, the President's Budget request funds five new manufacturing institutes).

Funding in FY17 further supports NIST's efforts to accelerate research and development at its national laboratories to expand labs-to-market transfers of innovations in manufacturing and other technologies. In a separate-but-related effort, the Budget invests $50 million in mandatory spending for a new competitive grant program within the Economic Development Administration (EDA) to incentivize partnerships between Federal Labs, academia, and regional economic development organizations enabling the transfer of knowledge and technologies from Labs to private industry for commercialization.

An additional $141 million investment is proposed for the Hollings Manufacturing Extension Partnership (MEP), which focuses on expanding technology and supply chain capabilities to support technology adoption by smaller manufacturers to improve their competitiveness.

The FY17 Budget request is responsive to pressing issues that require innovative and thoughtful solutions.

Recognizing that the national and economic security of the United States depends on the reliable functioning of critical infrastructure, the Budget focuses on improving the Nation's cybersecurity posture. This is an area of increased emphasis throughout the Federal government. As more and more sensitive data is stored online, the consequences of attacks grow more significant each year.

The President is establishing the Commission on Enhancing National Cybersecurity, comprised of top strategic, business, and technical thinkers from outside of Government – including members to be designated by the bi-partisan Congressional leadership. The National Institute of Standards and Technology (NIST) will provide the Commission with support to allow it to carry out its mission.

In addition, the National Telecommunications and Information Administration's (NTIA) FY17 Budget of $51 million will enable the agency to develop and implement policies to meet challenges related to Internet openness, privacy, security, and the digital economy. These resources will enable NTIA's BroadbandUSA to work with State and local governments, nonprofits, and researchers to overcome obstacles to increase broadband access and adoption in communities looking to expand their communications infrastructure.

The FY17 Budget request demonstrates the Administration's continued commitment to broadband telecommunications as a driver of economic development, job creation, technological innovation, and enhanced public safety. The President's broadband vision of freeing up 500MHz of spectrum (band) for commercial use, promoting broadband competition in communities throughout the country and connecting over 99 percent of schools to high-speed broadband connections through the ConnectED initiative will create thousands of jobs and ensure that students have access to the best educational tools available.

Strengthening U.S. Entrepreneurship and the Economy:

Entrepreneurship is a key driver of the economy and a pathway for millions of hard-working Americans to provide for their families. In support of that goal, the FY17 Budget provides for key investments in the U.S. Patent and Trademark Office (USPTO), the Minority Business Development Agency (MBDA), and the

Economic Development Administration (EDA).

The $3.2 billion request in FY17 for the USPTO will help American entrepreneurs and businesses bring their innovations to the marketplace. Funded entirely by fees from their users, USPTO continues to lead America's innovation community by making it easier for American entrepreneurs and businesses to develop, protect, and scale their inventions. These breakthroughs help pave the way for new technologies and jobs.

As the USPTO carries out its mandates under the America Invents Act, it remains focused on adopting policies and programs that embolden and strengthen the Nation's intellectual property system. USPTO recently opened four permanent regional offices across the Nation and will hire subject matter experts to reduce the backlog of unexamined patents while ensuring pending applications are reviewed expeditiously. USPTO also will implement administrative actions proposed by the President's Task Force on High-Tech Patent Issues and build an intellectual property system outfitted for the 21st Century.

Another critical priority in FY17 is to continue supporting the national growth of minority-owned U.S. businesses. The President's Budget requests $36 million for the Minority Business Development Agency (MBDA), a $4 million increase from the FY 2016 enacted level.

Minority-owned firms make a significant and valuable contribution to our economy and export at a higher rate compared to all U.S. firms. Additionally, with an eye on developing future leaders of America, $3.6 million is targeted for a new MBDA Business Innovation for Young Entrepreneurs program. This program will create a coordinated approach to engage, educate and build capacity among young minority entrepreneurs through competitive grants in regions of the U.S. with high concentrations of minorities, youth, and unemployment.

Finally, the Budget focuses resources on supporting economic growth in American communities. The FY17 request provides $258 million for the Economic Development Administration (EDA) to support innovative economic development planning, regional capacity building, and capital projects. Within this amount, $20 million is included for the Regional Innovation Strategies Program to promote economic development projects that spur entrepreneurship and innovation at the regional level.

EDA's Budget includes a variety of assistance programs, such as: $35 million for

Partnership Planning to support local organizations with their long-term economic development planning efforts and outreach; $50 million for Economic Adjustment Assistance aimed at critical investments such as economic diversification planning, and implementation, technical assistance, and access to business start-up facilities and equipment; and $85 million for Public Works infrastructure.

Fueling a Data-Driven Economy:

Data powers the 21st Century economy, and Commerce Department data touches every American and informs countless business decisions every day. The Census Bureau is committed to achieving a 2020 Census that delivers on the core mission to be as accurate as possible while keeping costs at or below the per-household cost of the 2010 decennial census. Streamlining, modernizing, and automating operations in preparation of the 2020 Decennial Census will potentially save the American taxpayer more than $5 billion when compared to the cost of repeating the 2010 Census design without sacrificing quality.

The Budget provides $1.6 billion to support key development and implementation of innovative design methods necessary to achieve these goals for the 2020 Decennial Census. This includes $103 million for the Census Enterprise Data Collection and Processing (CEDCaP) IT system that will provide a necessary foundation for newly-automated 2020 data collection and processing operations.

In accordance with the Federal Digital Strategy, the Census Bureau has set a goal to unlock the potential of our data and products to better meet the needs of its users. This Budget includes funding to enable users such as businesses, policy makers, and the American public to make better data-driven decisions based on enhanced statistics, easy-to-use tools, and standardized data elements.

The Budget provides for a planned cyclical increase for the Economic Census, which is the official five-year measure of American business and the economy. In addition, $115 million is requested for the Economics and Statistics Administration (ESA) and the Bureau of Economic Analysis (BEA) to leverage data to forge enhanced collaboration and expertise across the Federal government as well as provide timely, accurate, and relevant economic statistics in an objective and cost-effective manner. Included in this budget request is a proposal that will create a county level GDP measure to help policy makers at all levels of government and businesses better target investments to areas of need and measure the impact of these investments.

Supporting the Environment and Natural Resources:

The Department's commitment to supporting the environment and natural resources is demonstrated through its request of $5.8 billion for the National Oceanic and Atmospheric Administration (NOAA). The Budget, which is a $77 million increase over the FY 2016 enacted level, focuses on supporting NOAA's core missions, including deploying the next generation of weather satellites and observational infrastructure, fostering healthy marine resources, strengthening resiliency, and improving forecasting accuracy and lead times for severe weather.

To ensure the robustness of NOAA's observational infrastructure, the Budget provides $2.3 billion to fully fund the next generation of weather satellites. This includes $393 million for the Polar Follow-On satellite program enabling NOAA to maintain an optimal launch schedule to help minimize the risk of any potential gap in weather data in a cost-effective manner. The Department recently released its Commercial Space Policy and is exploring the viability of buying more weather data from the private sector.

The Budget invests $1 billion for the National Marine Fisheries Service and $570 million for the National Ocean Service, including $20 million for an expanded competitive Regional Coastal Resilience Grants Program to help reduce the risks and impacts associated with extreme weather events and changing ocean conditions and uses. The Budget further provides $9 million to help fishing communities, which face significant climate challenges, become more resilient to the impacts of fisheries disasters. These competitive funds will assist communities that have sustained a disaster to become more environmentally and economically resilient through activities such as ecosystem restoration, research, and adaptation.

An additional $12 million is requested for a new Integrated Water Prediction (IWP) initiative that will leverage the National Water Center in Tuscaloosa, Alabama. The IWP will link current expertise around the country to promote innovation in water prediction capability and services, such as providing high-resolution water information and critical water forecast information to local decision makers, emergency managers, and members of the public.

FY17 funding also supports maintaining research facilities, such as $4.6 million to begin prep work, planning, and design to replace the Northwest Fisheries Science Center facility in Mukilteo, Washington (on Puget Sound). The facility has deteriorated to a point that it poses a near-term safety risk and threatens NOAA's mission and operations in the region. NOAA conducts important multidisciplinary research at this facility which supports the commercial and recreational fisheries in the Northwest.

To better understand the impacts of increasing levels of atmospheric carbon dioxide on ocean chemistry and marine resources, the Budget includes $22 million for an expanded ocean acidification research program at NOAA.

Building a Weather-Ready Nation and evolving the National Weather Service (NWS) to become a more agile decision support organization capable of providing timely responses and increasingly accurate weather forecasts is a continuing area of emphasis for the Department. The Budget invests more than $1.1 billion for NWS, which includes funding to make the United States a Weather-Ready Nation (WRN). The Department focuses on continuing to evolve NWS into a fully integrated field structure issuing consistent products and services. To support a Weather-Ready Nation, the Budget requests a $5 million increase from the FY 2016 enacted level for the Advanced Weather Interactive Processing System Cyclical Refreshment, which is the telecommunications systems and cornerstone of NWS' field operations.

The Budget provides $24 million to complete design, acquisition, and construction of a multi-mission regional survey vessel (RSV), which will support fishery surveys critical to species management, habitat and hydrographic surveys, and disaster response. The FY 2017 funding, combined with the $80 million Congress provided in FY 2016, will help NOAA begin to recapitalize its fleet. Without further investment, NOAA's fleet is projected to decline by 50 percent (from 16 to 8 vessels) in the next 10 to 12 years.

Separately, the Budget includes $100 million in mandatory funds to begin construction on a second RSV as part of a multi-year NOAA fleet recapitalization initiative.

Modernization Initiatives:

Commerce is in the process of modernizing its infrastructure to protect the safety of employees and provide quality service to citizens. Many of these efforts will ultimately result in future savings. Commerce is requesting $12 million for the ongoing renovation and modernization of its headquarters, the Herbert C. Hoover Building (HCHB). This funding is critical to the completion of Phase 5 of an 8-phase project. Phase 5 is tentatively scheduled to begin in June 2017 and end in April 2019.

This renovation provides the solutions to replace major building systems (mechanical, electrical, plumbing, heating, ventilation, air conditioning, and life safety systems) that are beyond their useful life and deteriorating. Systems being replaced will be more energy efficient and cost effective to run. It also includes the Department's effort to improve upon space utilization, decrease reliance on leased space, and reduce the government's footprint.

The Budget supports $45 million for the Shared Services initiative that will enable bureaus to modernize mission support functions by leveraging information and services in the core areas of Human Resources (HR), Acquisition, Financial Management, and Information Technology (IT). The objective is to establish a new, customer-focused shared service model that will provide internal Department of Commerce customers with easier access to information. This includes high quality service, an improved customer experience, performance (management) measurement, external provider support, shared service independence, standardization, continuous process improvement and process transparency.

The upfront investment of establishing a shared service model is projected to generate significant cost savings by creating economies of scale and allowing bureaus and offices to pay only for the services they need rather than building their own infrastructure. Although actual cost savings are not known at this time, shared services initiatives tend to save organizations 20 to 40 percent by the end of the third year of their existence.

Integrating Innovative Best Practices into Core Agency Operations:

To further the President's goals of improving customer service and enhancing the efficiency of government, Commerce requests $6 million to support a Commerce Digital Services team, which will focus on two goals: 1) managing high priority projects to deploy digital solutions quickly across

Commerce bureaus, and 2) improving Commerce's systems to provide end users state-of-the-art technological tools.

Conclusion

The FY17 Budget continues investments in those priority programs that have a strong return on investment for our Nation's taxpayers and make a tangible difference in the lives of millions of Americans. During my tenure at Commerce, we have shown that, by working together, we can make significant strides toward setting a stable foundation for economic growth; providing U.S. businesses with the necessary tools and resources to succeed; and to ensuring that America continues to lead the global economy in the 21st century. With this budget, I am confident that we will keep America "Open for Business." I look forward to working with this Committee and the rest of the Congress to achieve these important goals.

Mr. CULBERSON. Thank you, Madam Secretary. It is very important for you as you go forward today from our hearing to take to heart what Chairman Rogers has said, and that is that this $2 billion increase in mandatory spending that you are assuming in your request is simply not going to happen, and it does make our job far more difficult; and that is the root of the problem that the American people face. The massive increases in mandatory spending are driving the annual deficit and the debt right through the roof.

So it is very disappointing and frustrating to see the increase that the administration has recommended through you to this subcommittee includes $2 billion in new mandatory spending that are simply not going to happen, and as Chairman Rogers pointed out, breaks the budget agreement.

INTERNET GOVERNANCE

I also want to mention something to you that is of particular interest and that I hear a lot about from my constituents, and that is Internet governance. We all have a keen interest in protecting the integrity of the Internet. My predecessor, Frank Wolf, was one of the first out of the gate to recognize the threat of Chinese cyber espionage. Frank, quite correctly, spotted the problem that Chinese were creating early on, and I was proud to support him in that effort to protect the agencies under the jurisdiction of this subcommittee from cyber attacks by the Chinese.

So we are all becoming—the whole country's increasingly aware of the threat of cyber espionage. And the committee, in the last couple of appropriations bills, has included language prohibiting the Department of Commerce from relinquishing responsibility for the Internet Domain Name System to any other country. Yet, despite these Congressional limitations, the Obama administration continues to plan to transition this responsibility to the global stakeholder community.

And I noted that at the Chinese government's world Internet conference, China appeared to move back towards their original belief that Internet governance is the responsibility of governments, which is a tenet not acceptable in a final Internet transition plan. We have had a very successful system in the United States of the private sector maintaining that responsibility. The Department of Commerce has overseen that, and we have put very specific language in last year's bill and in the 2016 bill prohibiting the transfer of that responsibility out of the Department of Commerce.

Since the Chinese seem to want to make the governance of the Internet the responsibility of government, I wonder if you could talk to us about why you believe the Obama administration and the Department of Commerce believe it is a good idea for the Chinese to have a say in how the Internet is administered.

Secretary PRITZKER. Mr. Chairman, first of all, let me start with the fundamental premise I think you and I agree on, which is the stability and security of the Internet, and the domain name system is of paramount importance.

The Department intends, you know, a rigorous review of the IANA transition proposal, which we have not received a proposal yet. When we think about the proposal, we believe that there are

a number of issues that would be absolutely paramount for us to even consider any kind of transition.

First, a system would have to support and enhance a multi-stakeholder model.

Second, it would have to maintain the security, stability, and resiliency of the Internet's domain name system.

Third, it would need to meet the needs of our global customers.

And, finally, it would have to ensure that we would have an open and free Internet.

And as it relates to ICANN itself, the governance of ICANN would have to be structured in a way that there could be no government leadership of that organization. So we share that fundamental principle.

There is no transition anticipated before the end of this fiscal year. We are expecting to see a plan proposal in mid-March, and, of course, when we receive that plan we will work very closely with Congress throughout that entire process.

Mr. CULBERSON. But of course, you recognize that we have prohibited any effort to move towards such a transition?

Secretary PRITZKER. I understand——

Mr. CULBERSON. This fiscal year.

Secretary PRITZKER [continuing]. I understand the language that has been put in appropriations. And so what we are going to do is receive a plan and then we will talk with you about it.

Mr. CULBERSON. I just really want to drive that home because the whole concept of a free, and open, and thriving Internet is completely inconsistent with the way the Chinese government approaches these things, and we want to keep the control of those Internet domain names here in the United States in the hands of the private sector has worked very, very well, so that it does continue to be free and secure.

How would you ensure, for example—if I could, the last question and then I will go to Mr. Honda—talk to us about how you would even begin to protect and address cyber security and privacy concerns, which is something of keen interest to all of us?

Secretary PRITZKER. Well, the domain name system and cyber security are two different issues. As it relates to cyber security, that is a paramount importance to the entire administration, it is something that we have been working very carefully and very closely on.

For our department, one of the things that we have done is really make sure that we have installed the Einstein 3A system, run by the Department of Homeland Security, throughout our entire department to protect ourselves. And I am happy to talk more about each bureau and what they are doing.

Mr. CULBERSON. Well, in particular what I was driving at, is your understanding of what this proposal would be, what would be the role of foreign governments in the——

Secretary PRITZKER. We are not looking to have a role of foreign governments. That is—forgive me—when I talk about the multi-stakeholder process, it is a process where it is not lead by governments but instead lead by the stakeholders in the Internet community.

Mr. CULBERSON. OK. Thank you.

Mr. Honda.

NATIONAL NETWORK FOR MANUFACTURING INNOVATION

Mr. HONDA. Thank you, Mr. Chairman. I have a question about the National Network for Manufacturing Innovation, better known as NNMI hubs. I believe that there are about seven of these industry-led public/private advanced manufacturing centers across this nation. In fact, my home of Silicon Valley was recently selected as a site for a new center on developing flexible hybrid electronics. And that is with the Department of Defense.

This center, which focuses on developing this potentially game-changing technology, took about $75 million in investment from DOD and raised over a quarter of a billion dollars from industry to build an innovation hub. And being from Silicon Valley, I fully appreciate how important it is that we focus on advanced manufacturing and potentially game-changing technologies to ensure that the next Silicon Valley is located right here in the U.S.

The vision of this network of advanced manufacturing hubs was to link all of them together through NIST to develop an innovation echo system across this country. In the fiscal year 2016 budget, NIST was given funding to coordinate this network and to establish NIST centers through an open call to agencies. Now until fiscal year 2016, only the DOE and DOD had the funds to raise the seed money for these hubs.

Now with last year's appropriations, other agencies now have the ability to compete for these seed funds to establish an advanced manufacturing center focusing on their technologies.

The questions I have are, what is the current status of the NNMI network in this role in linking these centers and establishing new ones? What are some of the successes from the seven NNMI centers so far? And what is your view of the role of the agencies in industry—agencies and industry/academia and the long-term success and sustainability of these hubs?

And then in your opinion, would these centers develop without seed funding from the agencies? And you may want to talk a little bit about the source of the seed funding and its anticipated, you know, growth in the next couple years.

Secretary PRITZKER. Well, first of all, I want to thank the committee for their support of the role of NIST in helping to set up the network as well as to authorize us to do our very first institute at the Department of Commerce.

You gave us $5 million for coordination which we are setting up the advance manufacturing national program office. And we, in fact, completed a review of all of the network, an annual report of the network, as well as we produced a strategy which we have recently distributed to all of you for what the network intends to accomplish.

You know, the successes of the seven existing institutes vary depending upon their age, the oldest being about three years old. I went and I have actually visited three of them myself. If you take the oldest, which is in Youngstown, Ohio, that does 3D printing, it is extraordinary what is happening there. It is, in fact, not just extraordinary what is happening there, it is a really by virtue of your creating the network, what is happening in other parts of the country, for example, in Texas, in 3D printing is really amazing.

So they started with 60 different participants, and today they have somewhere about 140. The institute in Youngstown, Ohio, has now partnered with University of Texas in El Paso, to—because El Paso has the greatest number of 3D printers. My point is, what you all are funding and are seeding with taxpayer dollars, I am a huge fan as a private sector person of this program, because as Congressman Honda said, most of the institutes are funded with some taxpayer dollars, the minimum requirement a 1 to 1 match, most are matched much more than 1 to 1 by the private sector, local government, and the universities, and the education partners.

It is also not just a big company game, but, in fact, I spent—I talked with one small business who is making some of the powders that are used in additive manufacturing. They said we never would have had the gumption to build a new $70 million plant to create these additive materials if this institute had not been created. I am simply giving you the example of one, I mean I could go chapter and verse on these things, but we do not have time today.

In terms of the role of academics, it is really critical that the private sector and the academia partner together because the academic world is really great at research, but often you need some help to go from research to market, that is the whole goal of the NNMIs. And they are playing an absolutely important role in doing the primary research, but they need the catalysts to the private sector to get those potential products out of the laboratory into the marketplace.

Seed funding is essential. I talked to—in each of the venues that I visited, the leadership in those communities told me we would never have come together organically, but it was the Federal government's wisdom to do these programs that was a catalyst for us to bring together. It is not just in one local city, they bring together regions and then now are partnering in different parts of the country. It is very exciting what you all have unleashed, and I think it is, you know, an extraordinary public/private partnership.

Mr. HONDA. Mr. Chairman, if I just may. It may be of interest to you, map out where a lot of these centers are, or the participating entities are with the centers so that members will see how, you know, how it affects their own communities and the participation of that so that it does not sound like it is just that one spot, but it is shared.

Secretary PRITZKER. I think that is a really good point, and I think if we map that and then follow it over several years, you will see then the role of the network is to expand. So the 3D printing is not just in Youngstown, Ohio, but it is in Texas and in other places, or you take composite materials——

Mr. HONDA. Sure.

Secretary PRITZKER [continuing]. Or the different—the seven or eight different——

Mr. HONDA. Yes. So, Mr. Chairman, as to answer the question, so what do I get out of it? Kind of an answer——

Secretary PRITZKER. Exactly. For everybody.

Mr. HONDA. Probably the last question I asked was the anticipated buildup, because of this process, what impact does that have in the future—this budget and in the future?

Secretary PRITZKER. Well, in our budget, we have asked for $22 million to do—you authorized us to do at least one institute, last year we asked for additional funding so that we could do at least another institute. And the first one that we are working on, we have just put out the FFO. And what is unique, if you recall me saying in my opening comments, is we at the Department of Commerce for our advanced manufacturing institutes, the private sector will determine the technology that we choose to fund, which I think is different than Department of Energy or Department of Defense where they are picking the technologies. And then what we are asking for in our budget is the ability to grow the number of institutes.

When you talk about the $2 billion of mandatory funding going forward, that is over a ten year period, and it is to stand up 27 institutes. That is what we had put in the budget.

Mr. CULBERSON. Thank you, Madam Secretary.

Mr. Rogers.

SOAR

The CHAIRMAN. Madam Secretary, I mentioned earlier about SOAR, the economic development group we put together with the governor. I visited last—couple weeks ago, I took the chairman of the FCC to two of the poorest counties in the country, very small counties, but where the local telephone co-op had installed high-capacity, high-speed cable—a remarkable thing in that small community. The FCC chairman was flabbergasted.

But one byproduct of that is, the Teleco guy told us that he has 150 people now working out of their homes, doing things for Hertz Rent A Car, and Hyatt Regency, and whatever. Those are jobs they can do at home even if they are homebound. So one of the major goals of SOAR is to lay 4,300 miles of high-capacity, high-speed cable, statewide, starting in eastern Kentucky.

So, Mr. Honda, in competition with your Silicon Valley, there is going to be Silicon Holler.

Mr. HONDA. Mr. Chairman, we really do invite that. And maybe he can look at cyber security as one of the hubs for the area.

The CHAIRMAN. At any rate, I welcome your help in that. It is an exciting thing, and it is beginning to pay fruit. And it is through the work of your department and ARC, and EDA and others, that we are trying to climb a very steep mountain.

INTERNATIONAL TRADE ADMINISTRATION—STEEL DUMPING

Let me briefly get back to the steel layoffs. Just before Christmas, AK Steel in Ashland temporarily laid off 700 employees in a very poor area. And those jobs are going to be almost impossible to replace, at least in the short term, until we get Silicon Holler going good.

Several of the steel companies around the country, in response to the dumping that has been showered upon them, several of them joined together and filed a complaint with the International Trade Administration and the International Trade Commission, accusing China, India, Italy, South Korea, and Taiwan of purposefully undervaluing their corrosion-resistant steel imports in order to in-

crease market share in the U.S. It is blatant, plain, open, purposeful, intended.

In the fiscal 2016 omnibus bill, we provided increased funding for the International Trade Administration's enforcement and compliance division. How is that working out? Can we hope to see some result out of that?

Secretary PRITZKER. Do you want me to answer?

The CHAIRMAN. Please.

Secretary PRITZKER. Yes, Mr. Chairman, first of all, I share your concern about the steel industry and the effects that unfair trade is having on communities throughout our country.

First, the money, thank you very much for the additional resources in fiscal year 2016. I think the goal is to hire 37 additional enforcement officers. We have our pedal to the metal to try and get these folks on board. It is a very, very high priority for us because we have—on our anti-dumping and countervailing duty efforts, we have over 300 orders in place, of which 149 relate to steel products. So this is a huge problem.

In fiscal year 2015, there were 62 anti-dumping and countervailing duty investigations initiated, of which about 40 were related to steel. And that is the highest number of cases we have had in any one year in the last 15 years. So we are seeing what your communities are feeling, and we are reacting as quickly as we can, we thank you with the additional resources to address these challenges.

The other thing that we are doing is—a couple things I want you to know that personally I have been doing. We hold the joint JCCT meeting with the Chinese. In November, I personally raised this with the vice premier about the dumping that is coming from China and the over capacity that exists in their country. I talked to a number of their economic officers as well.

We are now—and the vice premier has agreed, we are going to have a JCCT steel—say that three times fast—JCCT steel dialog is coming up in May, as well we are having—have, we are working in the OECD with our trading partners on steel over capacity.

So we are working on a multi-lateral level, at a bilateral level, we are doing our enforcement with as much of the resources that you have given us. It is very troubling what is happening to our steel industry. And steel capacity globally needs to be reduced.

And the other thing that we are doing—and I have spoken with the CEOs of a number of our steel producers—is to work to make sure that we have complete information as to what is happening so that when cases are brought, we can be as thorough as possible in prosecuting them.

The CHAIRMAN. Time is of the essence.

Secretary PRITZKER. It absolutely is. I could not agree with you more, Mr. Chairman.

The CHAIRMAN. People are getting laid off every day, and these companies are closing down. And unless something is done rather quickly, you are not going to have a steel industry in the United States of America.

Secretary PRITZKER. I am very worried about it. We are using all the resources that we have, we are very focused on the tools that we have in our tool chest.

The CHAIRMAN. Thank you very much.

Secretary PRITZKER. Thank you, Mr. Chairman.

ENFORCEMENT ACTIONS AGAINST STEEL DUMPING IN THE U.S.

Mr. CULBERSON. To follow up on that very quickly, Madam Secretary, what specific enforcement actions have you taken? You talked to the Chinese Premier, you are worried about it. I think Chairman Rogers raises a very good question, we certainly hear it in the presidential campaign, it is resonating with the American people. You have a tool kit at your disposal, this committee has given you the resources you need. What specific enforcement action have you taken against Chinese companies dumping steel in the United States?

Secretary PRITZKER. Chairman Culberson, what we do is really several things when it comes to enforcement. First thing we do is—writ large and then I will talk about steel—is work with companies with whatever trade barriers that they are facing.

In the case of steel, this is working with the Chinese to say you need to cut capacity. And, you know, the challenge will be, will they cut capacity fast enough to have our steel industry be able to survive? They have cut it some, but it is not fast enough at this stage. So there is the working with them.

There is our anti-dumping and countervailing duty effort, which is where we basically assess the situation and then if there is found to be dumping, and/or unfair subsidation then we put tariffs and duties on those goods and products. And as I said, fully half of the orders we have outstanding, 149 are on steel products coming in from outside the United States.

And then finally, we support the U.S. trade representative in WTO litigation. Because we are so familiar with working with the companies on their particular issues, we use our expertise to help the U.S. trade rep bring new cases.

And in the customs bill, which you all supported, there is now additional resources in the ITEC, and hopefully through the appropriations, the U.S. trade rep will get another $3 million to continue to pursue more within the WTO context.

Mr. CULBERSON. What I was driving at is, you know, talking to the Chinese does not help, working with them does not help, they are not likely to do this of their own free will. When have you dropped the hammer on them and actually hit them with a tariff?

Secretary PRITZKER. Well, we do it——

Mr. CULBERSON. That is what I am asking.

Secretary PRITZKER. Well——

Mr. CULBERSON. Give the American people and Chairman Rogers some good news here.

Secretary PRITZKER. Oh, lots. I mean, we have probably—last year I think we did, what, about 40 new tariff cases, or something to that effect. I will get you the exact number because I do not—please do not misquote—I do not want to give you the wrong numbers. But we had more, as I said, more tariff cases last year than we have had in 15 years, and of those, we had 62, to be precise 41 were steel cases. And I think, you know, the vast, vast, vast majority of those we found, you know, where we were—we had to put tariffs in place because there was dumping.

[The information follows:]

Question: Inform Chairmen Rogers and Culberson of specific steps DOC has taken to sanction China

Response: Information on steel trade enforcement case shared with Chairmen Rogers and Culberson staff on 3/2/2016. Phone call to Culberson on ZTE matter on 3/7/2016.

Mr. CULBERSON. That was the point of my question——

Secretary PRITZKER. I am sorry. Yes——

Mr. CULBERSON [continuing]. Because Chairman Rogers is exactly right, time is of the essence. These American jobs are disappearing and the Chinese will—they do not pay much attention to anything else.

Secretary PRITZKER. Thank you, Chairman Culberson.

Mr. CULBERSON. Thank you very much.

Mr. Jolly.

Secretary PRITZKER. We are pursuing this, and I will get you, Chairman Rogers, the exact number of new duties that we put in place over the last 12 months in the steel industry.

[The information follows:]

To Clarify:

For *Calendar* year 2015, there were 65 AD/CVD investigations initiated, of which 45 were of steel-related products.

For *Fiscal Year* 2015, there were 62 AD/CVD investigations initiated, of which 41 were of steel-related products.

In terms of new duties, there were 31 new AD/CVD orders in Fiscal Year 2015. The correct number of tariffs/orders put in place "in the last 12 months" is 16.

Secretary PRITZKER. What you have done by giving us additional resources is allowing us to investigate allegations more thoroughly, so that if there is dumping, we can put the duties in place. So we are very focused on this issue.

Mr. CULBERSON. And we will be paying close attention, Mr. Chairman, and aggressively watching this. Thank you.

Mr. Jolly.

HANGAR SPACE AT MACDILL

Mr. JOLLY. Thank you, Mr. Chairman. Chairman Rogers, Chairman Culberson, thank you for your support of some of the Gulf Coast of Florida's priorities in the last year. Madam Secretary, thank you for being here. I want to shift a little bit to a couple NOAA priorities.

One in particular that I know is of strong interest, concern to your department to the leadership at NOAA, and that is the notification in the last few weeks by our friends at the 6th Air Mobility Wing at MacDill, that they need their hangar space back for some KC 135s coming in and what that means for the disposition of the Hurricane Hunters and the NOAA fleet that, frankly, my predecessor was very instrumental in working with the department to make sure they were accommodated at MacDill.

I know the department and NOAA leadership has visited with at least two airfields in the area, one at Saint Petersburg/Clearwater Airport, which is in my district. It shares ramp space with the Coast Guard station. My understanding is there is ramp space, there is hangar space, there is office space for your 100 employees there, and that might be a feasible alternative. I know the Tampa

Airport also has land and ramp space. I'm not sure about their hangar and office space available. NOAA leadership has been there.

My question for you really is from your perspective and that of NOAA leadership, what you see as the options, the requirements, the budget, the timeline. I know MacDill and the Air Mobility Wing is suggesting no later than about this time next year. They need the hangar space back at MacDill, so I was hoping you could comment on what you believe the options are and, obviously, as well as whether or not resources are there for any potential move.

Secretary PRITZKER. Well, thank you very much. You know, as you mentioned, we have about 110 highly skilled employees in your—in the area who support our Hurricane Hunters, and it is very important to us to try and find a solution either at MacDill or in that area because we feel that we might lose 50 percent or more of our highly skilled, trained workforce if we were forced to move.

So, first, we are working close with the Air Force. We are looking at the options. We don't have a specific option right now that I can say we are going this direction or that direction, but what we will do is keep you very much apprised of it. But it is a priority for us to keep our skilled workforce, and so a massive move someplace else is—it would be a real—one, it would be expensive at a time when, as Chairman Culberson said, we are, you know, no one's flush with money.

And two is we have great people and we want to keep our people. So we are trying to figure that out within those parameters. So I have set out the priorities, but I don't have the solution.

Mr. JOLLY. Sure. Do you know, among the options, the posture of the department, if you will, or of NOAA leadership, whether to move within the area to an airfield that actually has existing facilities? To me, that would seem fairly seamless. I know there has been planning and design at MacDill to build a hangar, but that would be a multi-year project.

And maybe if you could also share—and I apologize, I don't know the answer to this, kind of a color of money question—would Commerce ever be involved in bricks and mortar infrastructure on a DOD facility, or do you rely just on leasing either at a DOD facility or at a private airfield like Saint Pete/Clearwater or the Tampa Airport?

Secretary PRITZKER. I can't—Congressman, I can't give you the specifics of whether we would spend money on DOD airfield or not. What I would say is the way I would look at this is to say what is the most cost effective solution for the taxpayer?

Recognizing that I do not want to lose the talent that we have because finding new talent, would be a disaster too. I think we have to weigh all those issues. You may know more specifics in terms of what the specific alternatives are. The team is working on it and have committed to get back to me. And as soon as we have our alternatives, we will work closely with you to make sure you understand how we are thinking about it.

Mr. JOLLY. Sure. And I appreciate that and I realize it is an issue for—that you rely on NOAA leadership for some direction on that. I will tell you, it is obviously of great concern to our area, I

know it is of great concern to NOAA to keep the Hurricane Hunters regionally in that area, it is a strong concern and priority of mine as well.

And to the extent that our Chairman would work with me throughout this cycle, I want to make sure if there are resource issues or other impediments to keeping them in the Tampa Bay Area where, geographically, I think it makes sense to keep them both for your workforce as well as for the missions that they run. I want to make sure that this subcommittee is a partner with you on that.

THIRD-PARTY DATA COLLECTION

Two other quick items I will just lay on the record in case we do not have time for a second round is we have worked very closely with NOAA on third-party data collection for ensuring that the data involved and decisions regarding fishery closures in the Gulf is sufficient.

This committee, together with the Senate, provided additional resources for additional third-party data, and I just want to lay on the record the intent, at least one part of the intent, of going into that was to bring the stakeholders to the table for the data collection at the beginning.

And I know so much of it will rely on peer-reviewed science and academia, but the intent, the true intent, going back a year was to make sure that our recreational, our for-hire, and our commercial all feel as though they have a seat at the table at the beginning of the data collection process, not at the end.

Secretary PRITZKER. Congressman, we agree with using third-party data, and we think it can help improve our stock assessments. And so our fiscal year 2016 priority has been to do, for example, red snapper evaluation, that is where we started and began.

So one of the things I think March 2 and 3 in New Orleans, we are meeting with the private sector to talk about what our priorities are so that they can actually figure out how, with the data that they collect, to be able to support our efforts.

Mr. JOLLY. Sure.

Secretary PRITZKER. So I think, we are big believers in those kinds of partnerships and appreciate your support in that respect. And as it relates to the Hurricane Hunters, we will stay in close contact as to what we find out.

Mr. JOLLY. Thank you. And on that, I know we do have to rely on academia to get the peer reviewed science right, but I don't want us to lose sight of the fact that we want this sector stakeholders to be involved in that process as well. So, thank you.

Secretary PRITZKER. As you can tell, I am a big believer in the sector stakeholders being our partners.

Mr. JOLLY. Thank you.

Mr. CULBERSON. Thank you, Mr. Jolly.

Mr. Palazzo.

SHARED SERVICES

Mr. PALAZZO. Thank you, Mr. Chairman. Madam Secretary, thank you for taking the time to meet with us today and answer our questions. As you know, the administration has recognized the

potential that shared services could be very beneficial for Federal agencies, both in terms of saving money, but also efficient delivery of services. I have seen this first hand in the private sector as well as in the public sector. I would like to agree that shared service is the way to go.

I notice that the budget supports it also with $45 million for a shared service initiative, and that Commerce has actually put out an RFP as well. Could you elaborate on your efforts, and what phase are you now? You got certain sites geographically in mind? And just tell me more about it.

Secretary PRITZKER. Sure.

Mr. PALAZZO. I think it is a great idea.

Secretary PRITZKER. Absolutely. Well, first of all, we had a retreat—we have been working on shared services to try and bring this together for several years, or a couple of years. We had a retreat in February, early February, of all the leadership of the Department, and the outcry for—demand for this service, because we are really struggling with HR acquisitions and IT support in most of our bureaus.

It is hard to attract the talent that we need in those bureaus, it is hard to get a service quality that befits the taxpayer. And so we are very grateful for NASA's support. I know the Stennis Center has been very, very helpful to us as we have been putting our plans together. Where we are, I think we are in phase 3—phase 3—of our process, where we are focused right now in putting together the HR component and going live this year.

So it is a high, high priority for us. All of our bureau leaders unanimously agreed that we need to have shared services in HR acquisition and IT. And there is a fundamental view that by doing this that we will be able to have increased accountability, increased transparency, and increased productivity.

So we are really committed to this effort, and I really appreciate the support that, as I said, NASA has given us through their shared services center in your district.

Mr. PALAZZO. Well, I am glad that you are consulting with other Federal agencies. I think there is a best practice out there for everything, and going and recreating the wheel, or having to struggle through, you know, alone is not necessary, because—and so I am happy to see that you are working with NASA. Because, I think, the same could be said for data consolidation.

It seems like, you know, everybody is talking about data consolidation and—but there is actually Federal agencies that have done it, and have done it well, and I wish these other agencies would look to them for their best practices, and government sharing it across the board. But I do look forward to maybe hearing more from your office if you could provide someone to come brief me.

Secretary PRITZKER. Absolutely.

Mr. PALAZZO. I would like that.

Secretary PRITZKER. Happy to do that.

BUSINESS NEEDS FROM THE ADMINISTRATION

Mr. PALAZZO. Well, thank you. Also, you are the voice of businesses in the United States. What is—and I read your bio and your introduction, and so you have talked to a lot of businesses, large

and I am assuming small as well, every category—what do they want out of this administration? What do they want to see Congress do? And I am from the private sector, I talk to a lot of businesses as well in my district, and I know what they are telling me, I am wondering what they are telling you, and what you are telling the administration.

Secretary PRITZKER. Well, you know, I hear a lot of different things, but there are some common themes. The first is, help us to sell our goods outside the United States. Help us to navigate these complicated countries where there is potential for our products. And so one of the things we have done is we have improved our market reports so that companies, large and small, but particularly small, you know, GE is going to figure this out, but the small company in any one of your districts needs more assistance. And, frankly, I ran companies that were more like those in your district and so that is one thing they want, help us do that.

So we have done a number of things in terms of both people, which is why we are asking for more resources for our foreign commercial service, but also we have created tools to help companies navigate throughout the world.

Second thing they ask for is, help us, we are struggling to find the workforce that can help us grow our companies. And so for the first time we made skilled workforce a priority of the Department of Commerce. And it does not mean—we are not trying to be the Department of Labor here, but what we are trying to make sure is that the voice of busines

And the President listened to us and said the voice of business needs to be present in all of those grants, whether they are from the Department of Labor or other parts of our government. So that is a second area where we have been very active.

The third is we need good information. Whether it is information coming from the American community survey or information coming from the weather service, we need actionable information that can help us make smart decisions. And so what we have done is we have created a data service within the Department of Commerce that is not only saving you money, and us money, and the taxpayer money in terms of producing data products because we are doing more efficiently with better quality people by centralizing that effort. But we are also getting better products out to the businesses in America so they can decide where to grow and how to grow. Those are just several things I have heard. I can go on and on.

Mr. PALAZZO. What about certainty and stability? You know, as a CPA, I like to be able to plan if I am going to make a capital investment or hire additional employees. And what I am hearing is that in this environment, people, they just can't do it, and it may be partly Congress, partly the administration. And, in addition, they are looking for tax relief and regulatory relief. Surely, you are hearing those themes as well.

Secretary PRITZKER. Of course. And so in terms of certainty and stability, that goes without saying. As we know, and I know— I have 27 years in the private sector—business people are good at making decisions, risk-based decisions, on their products, but when

you can't understand the landscape it is very hard to invest, and that is a big challenge.

Particularly with this challenge that has been affecting the market, right, our public markets. I am not sure—well, let's just say that has, I think, given people a lot of pause for thought lately. In terms of tax policy, there is absolutely an interest in seeing business tax reform. There has been, since the day I walked in to my position and, obviously, tax policy sits with the Treasury but as part of the President's economic team, we have been trying to figure out how to work with Congress to do business tax reform. And that is, obviously, a much bigger conversation than probably we have time for right now. But those are issues that are absolutely on the front burner for businesses.

Mr. PALAZZO. Madam Secretary, thank you. I know my time has expired. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you, Madam Secretary.

Judge Carter.

CYBER SECURITY

Mr. CARTER. Thank you, Mr. Chairman. Madam Secretary, I apologize for being late. We had weather delay, and that kept us sitting on the runway for a long time. But I am glad to be here, I am glad you are here with us today. Thank you for coming.

I want to talk about something that, at least on the subcommittees that I serve on, seems to be mentioned almost every day and that is cyber security, cyber threats. You mentioned the formation of a commission on an ANSII national cyber security. What are some of the goals you have for this commission and how will they interact with DHS, who has important efforts in the same arena?

Secretary PRITZKER. Well, first of all, Congressman, thank you for being here. And the cyber commission is something that the administration announced about a week or ten days ago, and we at NIST provide the secretariat, if you will, for the commission, it is a bipartisan commission.

And the goal is to address a number of issues over the next—that face us in terms of cyber security let's say over the next five years, it is not meant to be something for just this year. We play a important role at NIST, because first of all, we developed the cyber security framework. And the cyber security framework is both a language and a structure by which both the private sector and the public sector manage our cyber security.

And it is extremely important, and we are seeing a massive take-up on our framework. And, in fact, one of the charges for us in the whole cyber security national action plan is for us to up—the framework is, I think, 18 months old, it is not that old—but is for us to continue to evolve it, to modify it.

And the second thing that we are doing is working very closely with the chairman and vice chairman of this commission, Tom Donilon and Sam Palmisano, the former CEO of IBM, have said they are putting an agenda together and they asked us there to help them to, one, confirm this is a good agenda, but, two, then help operationalize the agenda. And our goal is to help make recommendations that, at the end of the day from the commission, that help both the private sector and the public sector.

Mr. CARTER. And this commission is made up of both government people and private sector folks?

Secretary PRITZKER. Yes, it is. And we absolutely made sure of that when the President was conceiving of the commission that the private sector as well as the public sector are represented.

Mr. CARTER. Well, I serve on this subcommittee, which almost everybody has a cyber issue in this subcommittee; chairman of Homeland Security, and we have a big cyber effort we have to deal with; and I am on defense, which, you know, it is cyber everywhere.

I sometimes wonder if we—and I don't mean this in any way a criticism of this commission— but if we do not continue to just keep adding more and more people, little pieces out there, and we are not all working together on that. And I would hope that anything new created would be at least communicating, not in silos, but communicating with others so that we really have a united effort in this fight.

Secretary PRITZKER. Congressman, the cyber commission is meant to be comprehensive, it is not meant to be siloed. The secretary of the Department of Homeland Security, he and I sat side-by-side with one another as this commission was being put together and announced. Our teams are working side-by-side with one another, and what we are trying—and our goal is not to have this be a little piece of the pie but instead a comprehensive look at what does the country need to do to deal with the challenges that we are facing.

Given that the Internet, as it was created, was not meant to carry the trillions and trillions of dollars of financial instruments that it is carrying; the trillions of dollars of commerce that it is carrying the very sensitive Department of Defense data; and on, and on, and on. So now what do we do since this thing kind of grew by itself, now what do we do to protect ourselves? And that is kind of the charge that has been given to this commission.

PROTECTING THE DATA-DRIVEN ECONOMY

Mr. CARTER. Well, you know, many of us—and I don't know how much time I have got—many of us are concerned about the increasing intrusions pose—continue to build on I think our data-driven economy. How would we reassure the American people by what the efforts that you are putting together that everything possible is done—being done to protect the data-driven economy? You can wake up in the middle of the night in cold sweats thinking about what could happen if they brought down the American data-driven economy.

Secretary PRITZKER. Absolutely. And, you know, your point that each of us has to do our part but that someone has to look at the whole, I think is absolutely right. And, you know, we at the Department of Commerce, our rule is to work with the digital economy on policy development. And that is one of the reasons in our budget we ask for funding for digital policy because, increasingly, the private sector is coming to the Department of Commerce and asking us to weigh in on whether it is issues of the open Internet, or issues of the Internet of things, or autonomous vehicles, or smart cities, or sensorized wearables, you know, privacy and na-

tional security issues as those come in contact with one another, the cyber security safe—you know, the U.S.-E.U. Safe Harbor, et cetera, et cetera.

I think it is very important that we develop a policy—more policy standpoints about this, but then from the standpoint also of protection. At NIST, one of the things we did we just opened the National Cyber Security of Excellence where we are working with the private sector, 23 different private sector partners, to look at the cyber security of everything from a police car, think of all the information in a police car, to our electric grids.

So this is a massive, as you point out, issue and requires us to bring both the science, the private sector together with the public sector. And we have to strengthen those engagements.

Mr. CARTER. Thank you for your answers, I appreciate it. Mr. Chairman.

NIST: CYBERSECURITY AND FOREIGN NATIONALS

Mr. CULBERSON. Thank you, Judge. Before I go to Mr. Honda, if I could very quickly, I want to bring to your attention, something I think I talked to you about last year. I know that the National Institute of Standards and Technology is responsible for creating the cyber security standards for the government, as well as you just mentioned the Cyber Commission at NIST is working with the private sector to see what those standards should be for everything from police cars to electric grid.

I have to tell you, I just got this assignment last January and one of my first meetings was with the interim director at NIST last spring and he really worried me, because he came into my office and said very cavalierly that he was allowing foreign nationals to come into NIST headquarters with flash drives and laptop computers. He alarmed me so much because I know of the problem of foreign nationals coming in with—I think if you walk into the Pentagon with a flash drive, you go straight to prison, I believe. Judge, is that about right? And I was deeply concerned.

So I asked the FBI to go out and meet with your folks out there at NIST. I understand from my committee staff that the FBI is satisfied that some improvements have been made. Could you talk to me a little bit about that? Because that is just unacceptable to allow foreign nationals with flash drives and laptops to walk into the center of where the United States Government is developing cyber security standards for the government and for police cars to the electric grid. I hope you have got a good handle on that.

Secretary PRITZKER. Well, Chairman Culberson, we take very seriously your concerns about the issue of foreign nationals at NIST and, frankly, we take very seriously the issue of cyber security as well.

Look, the threat environment continues to change that we have to balance that and that primary with the issue of to solve some of the problems and technologies that we need to do, we need to work with the best and brightest around the world. And so there is a certain amount of openness and cooperation that is required in order for us to solve some of the cutting-edge, global problems.

Having said that, Director Willie May, in thinking about the challenges of our foreign nationals, ordered an internal review of

how NIST manages its foreign guest researchers. And we have proactively initiated a number of improvements since our conversation last year.

We have issued, first of all, an overarching set of policies based upon not only the review that you had us do with the FBI, but also we recruited a security expert to be on staff who has a counterintelligence background. Also the Deputy Director reviews all requests for certain workers from certain countries. We have also required that non-Federal researchers are readily ID'd on their emails, so we know whether someone is, you know, a Federal researcher or a guest researcher.

We have also upgraded the physical security throughout our campus; cameras, access control, cipher locks, and things like that. And then we have done additional training of our NIST staff to make sure that they are sensitized to the potential challenges that a foreign worker could bring to our campuses.

Mr. CULBERSON. One of the other things I asked you to do was to be sure that you involve the FBI on a regular basis to come out and conduct reviews to ensure that that level of security was satisfactory in the eyes of the FBI. I think the FBI is truly the gold standard when it comes to protecting this Nation against a cyber attack. Is the FBI still reviewing on an ongoing basis how you are handling this at NIST?

Secretary PRITZKER. I do not know, Mr. Chairman, when the last time the FBI was there, it has certainly been within the last year. I do not know precisely what they are doing, but I will look into it and we will get back to you.

[The information follows:]

Question: Let Chairman Culberson know when FBI last engaged with NIST
Response: Department completed follow-up with Culberson staff on 3/17/2016.

Mr. CULBERSON. Thank you very much.

Secretary PRITZKER. Thank you.

Mr. CULBERSON. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman.

Just off my time, I will comment about the FBI. You may call them illegal status, but in the Asian-American community they have made some arrests at work, at home, and held people in jail without due process and then after a few months they drop the charges. And these folks have been left without their character, their jobs, their reputation, everything else like that, not even with an "I'm sorry."

So I think that we need to keep a rein on them and/or ask them what kind of training are they going through, because I think it is kind of a serious matter and it is getting our national attention.

So I want to support our enforcement agencies, but I also want to support and make sure that our citizens in this country are protected against undue intrusions in the name of security. So I think that we have to be careful how we go about doing that.

Thank you, Mr. Chairman.

SELECT USA

Madam Secretary, the SelectUSA Program seeks to grow foreign direct investments, as we are talking a lot about jobs and every-

thing else like that, and the foreign direct investment in the U.S. and create or maintain jobs here in the United States. So can you speak to the program's results since its creation in 2011 and how the additional funding would allow SelectUSA to expand its services?

Secretary PRITZKER. Thank you, Congressman.

You know, SelectUSA's job is to communicate the benefits of investing into the United States. And the United States, as we know, has been ranked multiple years in a row as the number-one place for investment, and our job is to connect investors to investment opportunities in communities throughout our country. SelectUSA has helped facilitate over $17 billion worth of investments. What we have done is develop a strong team of investment promotion specialists that help navigate both the U.S. Government, as well as help introduce investors to the state or local economic development officers.

We have held two investment summits to date, we have a third one coming this June. I invite all of you to attend, it is really terrific.

Mr. HONDA. Excuse me, where were they held, the two first ones?

Secretary PRITZKER. The first two, they are always held here to date in Washington, DC. The last one we had, over 2,000 firms were represented who wanted to invest in the United States. I think we had, every state had economic development representation, officers represented. So it was terrific. As the economic development officers tell me, this is a target-rich environment for them to find new investors into their states.

Obviously, we do not prefer one state over another. Our job is to bring folks together. We have also led road shows to various countries and to the United States, including 14 events just in the last year.

The additional funding, you asked what would that do. That would allow us to expand our services for investors and U.S. economic development officers in 14 additional focus markets. We have 32 markets total, we do not cover the 32 markets yet. And this would allow us to integrate the investment promotion into the U.S. and foreign commercial service apparatus.

And, finally, it would allow us to create public-facing foreign direct investment data analytic tools, so it is easier for an investor to figure out where they should put their plant or investment as it relates to, let's say, supply chain or our infrastructure or our talent pool, et cetera.

Mr. HONDA. To follow up on that, you said that you do not choose sites for them, but in our country we have depressed areas like our chairman talks about, certain communities that are being hit because of the energy shift. And it seems to me that some attention should be paid to those communities where they might want to be able to look at those communities and say what are some of the possibilities of investments there and what kind of activities can come up there, because there are a lot of skilled people out there. It is just the economic picture has changed and I think that some direction or some discussion around some of the impacted areas of our country might be important.

Thank you, Mr. Chairman.

Secretary PRITZKER. I appreciate that.

Mr. CULBERSON. Thank you.

Mr. Jolly.

Mr. JOLLY. Thank you, Mr. Chairman.

ARGOS

Madam Secretary, just one more quick topic and again focused on NOAA, so if it is something we need to just put on the record and get back to. But I appreciate the request for additional investment in ocean acidification and coastal resiliency.

My question is about the delay of the Argos Satellite launch, the data-collection program that I believe as late as last year the decision was made between NOAA and some of the industry partners involved in the Argos program to launch in 2019, and I understand in the request that is possibly delayed now as late as 2021. And if we need to take it for the record, we can, but this is a question given our mutual interest in both data as well as the quality of our oceans, the ability to monitor the data related to ocean quality, ocean acidification, resiliency, and so forth. How Argos contributes to the current mission and any fear of a lapse in data collection or compromised data as a result of a two-year delay from a schedule that as recently as last year was just agreed to.

So if you do have any information on that, I would be happy to—certainly appreciate any contribution. If not, we can do it for the record.

Secretary PRITZKER. So are you talking about our GOES–R program?

Mr. JOLLY. Right.

Secretary PRITZKER. Right, exactly. OK. So we had——

Mr. JOLLY. Argos.

Secretary PRITZKER. What? Yes, why don't I let our staff talk to you about it, because this is one that I am not as briefed up on.

Mr. JOLLY. Sure. And I appreciate that.

Secretary PRITZKER. Terrific.

Mr. JOLLY. If we can just put it on the record and follow up.

Secretary PRITZKER. I know more about our Polar Follow and our GOES–R program.

Mr. JOLLY. Right. No, Argos. Thank you very much.

Secretary PRITZKER. Thank you.

Mr. JOLLY. I appreciate it.

Thank you, Mr. Chairman.

[The information follows:]

ARGOS CONTRIBUTIONS TO GATHERING OCEAN DATA AND INFORMATION

Argos-DCS collects, processes, and disseminates environmental data from more than 14,000 fixed and mobile platforms worldwide. NOAA relies on the Argos system to collect worldwide ocean data (e.g., temperatures, air pressure, currents, and salinity) from moored and drifting buoys and submerged profiling floats. In addition to ocean data, Argos provides data for wildlife studies, monitoring and managing fisheries, non-environmental applications (i.e., monitoring vessels to improve maritime transportation security, tracking humanitarian supplies), and other environmental applications (i.e., environmental safety, hydrology, and marine pollution response applications).

EFFECTS OF A 2-YEAR DELAY OF ARGOS

The Department of Commerce is not afraid that a two year delay will compromise the Department of Commerce's ability to monitor the data related to ocean quality and resiliency at this time. The Argos constellation is currently healthy and NOAA and its partners will continue to monitor and manage to ensure constellation health. The Department and NOAA will reevaluate the ARGOS constellation needs as a part of the FY 2018 budget process.

Mr. CULBERSON. Mr. Palazzo.

BUILDING A WEATHER-READY NATION

Mr. PALAZZO. Sure. You know, I am here, I have got a chance to ask you another question, I will take it.

You mentioned in your testimony building a weather-ready nation and you mentioned of course NOAA National Weather Service. And we have in my district a specific interest with the National Data Buoy Center, which is extremely important to help calculate natural disasters and patterns in our oceans. Can you expand?

I mean, right now I am getting all kind of weather alerts back home, tornado watches and stuff like that. So it is on my mind. Maybe a little bit more about what it means to build a weather-ready nation.

Secretary PRITZKER. Well, what we are trying to do at a large, philosophical level at the National Weather Service is as follows, is to make sure that we are not only collecting enough information, that the data is good and that we have information, but it is no good if we just know it. We have to be able to get it out to the first responders, to the emergency managers, to mayors, to governors, so that they can do something with the information that we have.

And so we are trying to evolve the Weather Service from one that is just focused on having the most accurate information to one that makes sure we are having the most accurate information and getting it into the hands of those people who can take action to protect life and property.

And so that means we need to think about making sure that we have our resources first of all as it relates to buoys and things like that, and data collection. In fact, in our budget request we are talking about trying to expand our Automated Surface Observing Systems to not only extend their life, but improve their functionality.

And in fact I have these great maps that the team did for me about the amount of coverage we have today and the amount of coverage we would like to have, so that we can have better data information that we think we can achieve and we have some money in our budget for that. The other is to improve our Doppler radar system.

But fundamentally, having good information is not good enough. I mean, if people are dying or property is being hurt, we need to make sure that we are getting that information to the folks on the ground who can do something with that information. Now, sometimes that means responding to a hurricane, but it also means a better understanding. What is going to happen, what kind of flooding, what kind of drought is being predicted, what kind of extreme weather should we be thinking is coming? And that is a lot also of what we are doing with the Weather Service.

So a weather-ready nation is one that is more than just knowing what the weather is going to be in the next hour, it is being able to get enough information early enough so that actions can be taken to protect life and property.

Mr. PALAZZO. Thank you.

OCEAN EXPLORATION AND RESEARCH

Mr. CULBERSON. Thank you.

Madam Secretary, half of the United States actually lies under the ocean and under the exclusive economic zone of the United States, and the Office of Ocean Exploration and Research conducts mapping—oh, excuse me, Mr. Carter, forgive me.

Mr. CARTER. That's all right. I will catch up after you. Go ahead.

Mr. CULBERSON. Excuse me, I am sorry about that.

Anyway, I want to ask, in the budget request that you submitted to the committee you propose cutting that program by nearly 40 percent. Yet the mapping that they are doing, the cataloging of the mineral resources that are out there is extraordinarily important, particularly in light of the fact that the Chinese have locked up 98 percent of the world's rare earth elements and it is already apparent that there are vast amounts of rare earth elements out there.

That is an extraordinarily important program that the committee strongly supports. I am very passionate about it, and could you talk to us about why you proposed cutting that program by nearly 40 percent? I hope that is not something that you intend to do. I would hope you will be as strong a supporter of that program as this committee is.

Secretary PRITZKER. Well, Mr. Chairman, first of all, NOAA's ocean exploration program does very important work and, you know, both NOAA and I support the program that we do. What we are trying to do is weigh competing demands on our NOAA budget which led to us decreasing the request for that program. But what I would assure is we run a skilled program at the proposed funding level.

The other thing we do, exploration of rare earth minerals is something that is work that is supported by our proposal and will improve our knowledge of the possible location of these resources within our U.S. exclusive economic zones.

So we are trying to balance our budget here, but also to make sure that we are better understanding exactly what are the assets that we have within our oceans.

Mr. CULBERSON. Well, I will pass to Mr. Carter, but I want to recommend to you that the work being done for example by Dr. Robert Ballard and the Nautilus in the private sector, he matches every dollar that you invest and that NOAA invests in the work that the Nautilus does, he matches it with at least two dollars of private funding and they are doing extraordinary work. So I hope that you will continue to support that program aggressively, because it is a great benefit to future generations.

Secretary PRITZKER. Terrific. Thank you.

Mr. CULBERSON. And I recognize Mr. Carter.

Thank you.

PROTECTING INTELLECTUAL PROPERTY

Mr. CARTER. Thank you, Mr. Chairman.

Madam Secretary, you mentioned the good work that you are doing to spur innovation and technology. What steps are you taking to address the intellectual property theft perpetuated by foreign nations and specifically China?

Secretary PRITZKER. It is a challenge. What we have done is we work with the Chinese. And I will begin with the Administration's position, which is this went all the way up to President Obama and President Xi, where President Obama and President Xi agreed that we would not tolerate intellectual property theft for commercial purposes between our two countries. And that was a very important marker to set down and something that we are watching very carefully as to what has occurred since last September when that agreement was reached.

And the second thing that we do through our dialogues and our work through the International Trade Administration, we work with China on, you know, I work with different companies that have various issues with the Chinese Government, raising specific issues as they arise with their government as it relates to intellectual property theft.

And I have been a consistent and strong voice for intellectual property protection as it relates to the Chinese. It is a challenge.

Mr. CARTER. Well, you know, I come from a world where actions have consequences. And it is great to get two heads of state to sit together and say, boy, this is really a bad deal, this should not be happening. But the next question is, what happens if it is happening and what are going to be the consequences to the thieves that are stealing the intellectual property? And I do not think we get to that level of addressing it. And you do not stop bad behavior without having consequences of bad behavior.

And I heard a story from a small, relatively small company about how they had grown to the point where they could utilize the Chinese market to build their product better, except that within 18 months the Chinese had stolen everything they had and basically were putting them out of business.

And, you know, you hear these stories all the time and you hear the stories from the big guys who say they are stealing our best ideas we have had recently. And having tried, at least had a few intellectual property cases filed in my court, amazingly enough, what you steal today becomes irrelevant eight months from now in some industries, because it is already old data or old information. And so the courtroom even does not reach the consequence area before everybody says it is not worth fighting over.

They are going over a line on this. We have to do something to get their attention or they are not going to stop.

Secretary PRITZKER. Well, the President has also created the ability to do sanctions against bad actors who are stealing intellectual property of our companies. And so that sits in place and the utilization of those sanctions is something that the decision to do that resides above my pay grade.

Mr. CARTER. And I understand that. I just hope that we not only do that as an example, but let the American public know it is an example and we are pointing the finger at people that are stealing.

Secretary PRITZKER. I will be sure to share that.

CURRENCY MANIPULATION

Mr. CARTER. And in the same scope of relationship, in your opinion, how big of a problem is currency manipulation and what steps are we doing to limit its impact on international trade for the country?

Secretary PRITZKER. Well, you know, currency manipulation resides in the Treasury Department, addressing that, I think that is appropriate. There is one place where the hammer exists, if you will.

Having said that, the Customs bill, which you I believe will get signed into law tomorrow and you all passed, gives the Treasury Department and the Administration more tools to deal with currency manipulation and it is something that is very welcomed, frankly, by all of us in addressing those challenges.

We at the Department of Commerce particularly would deal with currency manipulation if it was brought up as something that was viewed as a subsidy, that is technically the way it would enter into the Department of Commerce's AD/CVD, our Anti-Dumping and Countervailing Duty processes. But really most of the tools exist and the most useful tools exist at the Department of Treasury.

Mr. CARTER. As you deal with industry, do you hear complaints about currency manipulation as making an unfair playing field for our products and services?

Secretary PRITZKER. To be honest, that is not the big—I have heard there are selected industries that have raised that, but intellectual property protection is much bigger——

Mr. CARTER. It is a much bigger deal.

Secretary PRITZKER [continuing]. Much broader, of much greater concern to our industry.

Mr. CARTER. I agree with that.

Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you.

INTELLECTUAL PROPERTY SANCTIONS

Madam Secretary, there is a common theme here that the Chinese have continued to be one of the worst actors in the world when it comes to stealing intellectual property, whether it be dumping steel or currency manipulation, but I have to tell you, we just have not heard enough. I am glad to hear you have imposed some tariffs.

What sanctions has the Administration imposed on the Chinese for the theft of intellectual property?

Secretary PRITZKER. I will have to get back to you on that and give you an outline of what has been done.

[The information follows:]

Strong protection and enforcement of intellectual property rights in China is a high priority for the Administration and the Department of Commerce.

We have continued to raise our concerns with the highest levels of the Chinese leadership in settings such as the U.S.-China Joint Commission on Commerce and Trade (JCCT).

However, counterfeiting and piracy rates in China remain unacceptably high.

Our colleagues at the Office of the United States Trade Representative (USTR) have identified China as a Priority Watch List Country in annual Special 301 reports; our International Trade Commission (ITC) colleagues have issued limited as well as general exclusion orders against multiple Chinese suppliers of patent-infringing goods; and the Department of Justice (DOJ) has obtained indictments against several Chinese state actors involved in the sort of cyber theft you highlighted.

Last year, the President issued the Executive order on "Blocking the Property of Certain Persons Engaging in Significant Malicious Cyber-Enabled Activities," which targets the threat posed by malicious cyber actors Specifically, the Executive Order authorizes the Secretary of the Treasury, in consultation with the Attorney General and the Secretary of State, to impose sanctions on individuals or entities that engage in malicious cyber-enabled activities that create a significant threat to the national security, foreign policy, or economic or financial stability of the United States.

I defer to the Secretary of the Treasury on any actions he may have taken pursuant to the Executive order.

Mr. CULBERSON. My impression is there have not been any sanctions. I mean, this is the equivalent of cyber warfare that the Chinese have declared on us some time ago and it really is about time the United States hammered them back. This is just not acceptable.

When you go to these briefings with the FBI, you discover that the Chinese have engaged in the largest theft of property probably in the history of mankind. It is an extraordinary loss of intellectual property. Mr. Carter is exactly right. Small companies, large companies, on a massive scale we are seeing a level of intrusion that is absolutely unheard of. They stole all the government records on government employees. And if it had been semi-tractor trailer trucks backed up to a government office loading file cabinets, I think the level of outrage would be greater, but that is essentially what the Chinese government has done.

So I hope you gather of course from the questions that you have heard from all of us here today that we are counting on you and this Administration to respond, whether it be dumping steel, theft of intellectual property, protecting the Internet, protecting our privacy as Americans from governments around the world attempting to interfere in the way the Internet is regulated. We need action and we are looking to you to do so, and this committee will be aggressively working to ensure that that action is taken.

Mr. Honda.

Secretary PRITZKER. Absolutely understood. Thank you.

Mr. CULBERSON. Thank you, ma'am.

Mr. HONDA. Thank you, Mr. Chairman.

Two quick questions. One has to do with census preparation, the other is the Minority Youth Entrepreneurs.

Could you please talk about some of the budget problems we might be seeing a few years from now if the budget for 2020 census preparation activities were to be greatly reduced below the requested level for fiscal 2017 and what cost-saving innovations for the next decennial census might not be achievable under a greatly reduced budget.

And then the other question would be Minority Youth Entrepreneurs. The Department's request for the Minority Business Development Agency contains a new $3.6 million initiative focused on

business innovation for young entrepreneurs. Madam Secretary, could you please describe the ways in which you anticipate this initiative will help enable young entrepreneurs to create jobs and spur innovation in the economy?

Secretary PRITZKER. Absolutely.

So let me talk first about the 2020 census, which is at a very critical phase, as we are all aware. Our commitment is to try and save $5 billion, but in order to do that we have to spend money. And this is one of the critical years and that is why we have asked for a significant increase for the Census Bureau to $1.6 billion.

We released an operating plan for the census in October, that is three years ahead of what the 2010 cycle is. In our operating plan we detail what we are going to do and the milestones that we set out for ourselves for all of us to know whether we are on track or not to have a 2020 census the way we want.

And the thing about the 2020 census is we are trying to do four main things that are new. First is use administrative records. And if we want to use administrative records and we have gotten great access to many, many records, some of which though we would like to get access to that need legislation, but many that we have gotten, we have got to test the efficacy of using administrative records. We cannot just use them and hope that it is going to give us an accurate census.

The second is we are re-engineering the field operations to be more efficient, so that when we send people into the field we know that there actually is someone at the other end of the doorbell to answer the door.

The third is we want to collect more information over the Internet. As you can imagine, we need to make sure it is secure, we need to make sure we know the person who is responding is the person they say they are. And so there is a lot of testing that has to go on with that.

And, fourth, we have to have a communications plan with the American people that explains here is how the census is going to work in 2020. So there are a lot of things that need to be tested this year before we can do what we call an end-to-end test which has to be done in 2018 in order to lock down the census for 2020, make any final adjustments and lock down the census for 2020.

So this year, one of the things that we'll do is a very significant test in both Houston and in Los Angeles and we will also test—we decided not to use the bring-your-own device but instead we are leasing devices where we're going to control the operating systems being used. All the software is our software, but this way we will also be able to control the operating systems that are being used.

So there is a lot that is happening with the census. The other thing that is important that we need to spend money on now is we are putting in place the technology and the systems to be able to assimilate all the information that we are taking in. That has to be completed and tested also now so that we know that that works at the time of the 2020 census.

So I think to date we are meeting our milestones. We work—my deputy is briefed monthly on where we are at. I feel that we are very—and I am briefed, you know, no less frequently than quarterly on exactly where we are at. So we are very much on top of

it, we know what is at stake, but we need the money to be able to actually execute this year. So it is a very important year for the census.

As it relates to MBDA and your question about MBDA, we have proposed to add two programs. First is the minority—program for minority young entrepreneurs which is really—what we know is from research. If there are minority run enterprises in a community, there is less crime. So we need more minority run businesses in the communities that are having the biggest challenges.

So what we want to do is add youth business innovation centers in different communities. We want to have lab-to-market forums. We want to have venture capital forums in parts of our country that have received less attention as it relates to entrepreneurship.

So it is very exciting. It would be a Federal grant program that we are proposing and one that we spent a lot of time crafting. And one that, frankly, given the unrest in places like Ferguson and Baltimore, I think have the opportunity to help more businesses spring up in those neighborhoods.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. CULBERSON. Madam Secretary, we appreciate your service to the country. In conclusion, we will be following up and deeply appreciate your attention as we discuss making sure we are protecting American industry, making sure that we are keeping the Internet safe and secure against cyber attack.

And the Founding Fathers entrusted—one of the most powerful checks and balances we have in our Federal system is the power of the purse, and over the decades Congress entrusted that authority to the Appropriations Committee and it was in turn entrusted to the subcommittee chairman. And as the new chairman of the subcommittee, the new rule is, for every agency under our jurisdiction, if you want access to our hard-earned tax dollars, follow Federal law as enacted by Congress and that will be true of all the agencies as well as the grant recipients. That is why I will be paying particular attention to sanctuary cities, for example. If they want access to our hard-earned tax dollars, they are going to have to follow Federal law.

We will work hard with you to make sure that we give you the resources you need to fulfill the mission that you have, but we really want you to be aggressive in protecting American industry and protecting the privacy and security of Americans in this digital age as Mr. Carter just pointed out because the Chinese are engaged in cyber warfare against the United States. They have stolen virtually every piece of intellectual property in this country and it's just unacceptable and it has just got to stop.

And we will work with you to make sure you've got the resources you need, but we will also be exercising aggressive and good stewardship and working with you in a cooperative way using the power of the purse entrusted to the Congress by the founders. And we deeply appreciate your service to the country and thank you very much for appearing to us today and the hearing is adjourned.

Secretary PRITZKER. Thank you.

The Honorable John Culberson
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the Department of Commerce FY 2017 Budget Request

FirstNet
$7 billion of mandatory funding is available to establish a nationwide interoperable public safety communications network.

Question: How is FirstNet working to ensure that this money is spent appropriately and can meet the needs of our nation's first responders?

The Committee understands that FirstNet recently released its Request for Proposals to build the national network.

Answer: The funding that FirstNet received from spectrum auctions is a significant investment, which Congress made possible, towards the successful deployment, operation, maintenance, and recapitalization of the Nationwide Public Safety Broadband Network (NPSBN). From the outset, FirstNet has taken its responsibility to ensure the deployment and operation of the NPSBN very seriously and is doing so in an efficient, expeditious, and responsible manner.

FirstNet has developed a robust financial and business model, which has been incorporated into its Request for Proposal (RFP). This model is designed to: (i) create incentives to ensure public safety's needs are met; (ii) maximize the value of the excess network capacity through Covered Leasing Agreements, authorized by the Middle Class Tax Relief and Job Creation Act of 2012 (Act), to benefit both FirstNet's network partner(s) and public safety; and (iii) enable FirstNet to receive regular, periodic fees and other payments to ensure FirstNet's long-term sustainability. In addition, the RFP issued in January 2016 is based on 16 high-level objectives that were developed through extended consultations with the states, territories, and public safety stakeholders. This objectives-based approach enables prospective offerors to come to the table with the most creative proposals consistent with each offeror's network and business model rather than pre-determined requirements. FirstNet expects this approach will maximize network efficiencies and functionality while minimizing time to deployment. These 16 objectives will serve as the basis for evaluating RFP responses. The fact that the single prime contractor awardee of the RFP process will only be paid upon successful delivery of milestones in the rollout of the NPSBN is fundamental to the acquisition approach.

Initially, FirstNet's Chief Financial Officer (CFO), in coordination with the various divisions of FirstNet, is responsible for the development of an annual budget that must be approved by the FirstNet Board. FirstNet's CFO develops the budget on an annual basis following federal financial practices and standards and general accounting principles and

procedures. Members of the CFO team work on the planning, preparation, development, and submission of each division's budget to the FirstNet Board. Pursuant to the Act, an independent auditor also audits the FirstNet budget in accordance with general accounting principles and procedures applicable to commercial transactions. This process ensures that the organization is held to the highest possible accounting standards and minimizes inefficiencies. FirstNet provides the annual audit reports to Congress, briefs Congressional staff members on the contents, and posts them to the FirstNet website. This process, along with each of FirstNet's internal controls, helps ensure fiscal efficiency, accuracy, and responsibility. Additionally, FirstNet has partnered with the Department of Interior (DOI) to augment and support our own in-house procurement and contract administration expertise and capabilities. FirstNet recently completed its 2015 audit, which has been provided to Congress, and which highlights the financial rigor FirstNet routinely applies to its financial management.

Currently, the two principal efforts of FirstNet, state consultation and the acquisition of a network partner to build and operate the NPSBN, are well underway and both are vigorously tracked for cost savings and effectual execution. Consultation activities with the states, localities, tribal nations, federal partners, and the public safety advisory committee (PSAC) are a fundamental step towards the successful deployment of the NPSBN. Given FirstNet's finite resources, internal structures are in place to ensure that such funds are spent appropriately to maximize potential end-user impact. Through the consultation process, FirstNet has received valuable input from public safety stakeholders that helped shape FirstNet's network RFP and allowed FirstNet to focus its limited resources on meeting public safety's needs and objectives.

Question: How will FirstNet oversee what could be a $6.5 billion contract?

Answer: FirstNet has taken a number of steps to ensure that once a partner(s) has been awarded the contract for the deployment of the NPSBN, there will be mechanisms in place to ensure that the partner(s) adheres to the terms of the contract. FirstNet has built an organization that will be focused on oversight of the contractor in all aspects of meeting public safety objectives and plans to enter into a true public-private partnership as envisioned by Congress and the Act. FirstNet has established a cadre of senior management team members with significant private sector backgrounds in technology, program management, contracting, and management. FirstNet's Board will apply stringent oversight to all activities of the team as we ensure that our contractor will deliver on the nationwide network.

FirstNet established an Enterprise Risk Management (ERM) Program which is designed to address the full spectrum of FirstNet's risks and opportunities by proactively identifying and mitigating day-to-day and strategic risks that threaten the success of its mission. FirstNet also has an internal controls team and a Compliance Committee, both accountable to the FirstNet Board, to ensure proper oversight is in place. In addition, FirstNet is putting in place significant governance structure and resources to closely

oversee and coordinate the contractor's performance against the detailed critical path to a successful deployment of the network. In this regard, FirstNet has established a Program Management Office that will support regular and thorough review of program metrics and risks to ensure contract compliance and contract execution.

Question: Does FirstNet have the appropriate management and oversight structure in place?

Answer: Yes. FirstNet is unique in that it is administered in a similar manner to a private sector entity. Under the Act, FirstNet is governed by a 15-member Board that provides strategic direction and oversight. Consistent with that statutory model and best practices, the Board has appointed a Chief Executive Officer who is responsible for the overall management of the organization. The CEO reports to the FirstNet Board and is supported by the FirstNet President and a "c-level" group of individuals, including a Chief Financial Officer, a Chief Information Officer, a Chief Procurement Officer, a Chief Counsel, a Chief Technology Officer, a Chief Customer Officer, and a Chief Administration Officer. Each of these individuals has significant management roles and responsibilities that ensure sufficient structure exists within the FirstNet organization to provide both the necessary management and support for all aspects of the program.

Like all federal organizations, agencies, and departments, FirstNet is subject to Congressional oversight. Since its inception, Congress has held a number of hearings to fulfill its role in providing oversight over FirstNet. The latest hearing took place in February 2016. Within the Department of Commerce, FirstNet collaborates with the Secretary's office and the National Telecommunications and Information Administration (NTIA) to ensure appropriate oversight, and FirstNet is also subject to oversight by the Inspector General of the Department of Commerce (IG), which has conducted several audits of the organization's activities. In addition to IG audits, the U.S. Government Accountability Office (GAO) has conducted an audit of FirstNet. FirstNet has developed, and submitted to the IG, Action Plans outlining the steps it will take to implement all IG recommendations and the IG has accepted these plans. Additionally, with respect to the GAO audit, FirstNet provided a Statement of Actions taken in response to the GAO's recommendations. FirstNet provides documentation demonstrating implementation of each IG and GAO recommendation when the applicable actions are completed.

Question: How will FirstNet ensure that the needs of Federal stakeholders, in addition to those of State and local agencies, are adequately addressed in building this system?

Answer: FirstNet has been working closely with the major federal agencies to incorporate their mission needs in its planning and to demonstrate the value of FirstNet. To further those goals, FirstNet established a team dedicated to engaging with federal stakeholders. FirstNet hosted a Federal Open House on April 14, 2016 at the U.S. Department of Commerce, with over 30 participants from numerous agencies to engage with FirstNet on technical topics and provide a better understanding of FirstNet and its importance to the public safety mission carried out by many federal agencies. FirstNet also recently briefed the senior leadership of all agencies inside the Department of

Homeland Security (DHS) on FirstNet's progress and DHS's ability to leverage FirstNet effectively.

NOAA IT Security
In July of 2014 the Commerce IG issued a report finding several significant security deficiencies in NOAA's information systems that manage the weather satellites. In fall of 2014, an outside attack compromised several NOAA websites. While addressing this attack, NOAA inadvertently stopped the flow of crucial satellite information to the National Weather Service. Fortunately, in this case, no weather forecasts or warnings were disrupted.

Question: How does the Department ensure that all systems meet relevant IT security requirements? Is this method sufficient?

Answer: The Department conducts annual security assessments of selected IT security controls through its security compliance review process in addition to reviews conducted by the Office of the Inspector General. This methodology is in alignment with NISTs Risk Management Framework and Special Publications which are generally accepted best practice throughout government. The security control reviews are an integral part of our Information Security Continuous Monitoring program. The Department plans to strategically deploy the DHS Continuous Diagnostics and Mitigation (CDM) program tools to increase our automated ability to conduct these reviews by FY17Q1. The Department is undergoing assessments of high value assets conducted by DHS and continues to participate in DHS weekly critical vulnerability scans of public-facing DOC computers. While no entity, private or public, can completely guarantee the security of its systems in this age of consistent and increasingly sophisticated threats, the Department believes that this risk-based approach provides a balance between security, cost, and mission effectiveness.

Question: Have the issues identified in the 2014 Commerce IG report been fully addressed? If not, what remains to be addressed and why?

Answer: NOAA continues to work to implement the action plan on its information systems in response to the 2014 Commerce OIG report, "Significant Security Deficiencies in NOAA's Information Systems Create Risk in Its National Critical Mission." Six of the thirteen Commerce IG recommendations have been implemented and efforts are ongoing to continue implementing rigorous security controls.

The President's FY 2017 Budget requests an increase of $6.2 million to provide NOAA with resources necessary to implement changes to modernize and streamline NOAA's IT systems, enhancing system resilience and cyber security.

Some of the currently ongoing activities funded by prior year appropriations include:

- Continued coordination with the Department of Defense (DoD) to improve security perimeter controls between the Defense Meteorological Satellite Program (DMSP) system and the NOAA Polar Operational Environmental Satellite (POES) Ground System, and to monitor DoD's ongoing commitment to assess controls effectiveness and manage security risk for the DMSP system. The initial boundary protections have been deployed for Integration and Testing, with an expected completion date for Initial Operating Capability by the end of FY 2016.

- Continued work to complete re-design and documentation of the Geostationary Operational Environmental Satellite (GOES) interconnection and support agreement with the National Weather Service's Space Weather Prediction Center (SWPC). These efforts are in the final stages of deployment and are expected to be in place by the end of 4Q FY 2016.

- Work continues on the Environmental Satellite Processing Center (ESPC), Search and Rescue Satellite Aided Tracking (SARSAT), and POES to complete efforts to document, prioritize, and implement safeguards to protect systems from high-risk software vulnerabilities, but work remains to modernize the GOES system components. This is a phased effort consisting of an initial planning phase expected to conclude before the end of CY 2016, and followed by an implementation phase based on the plan developed under the initial phase, and will continue in FY 2018 and beyond.

- Work remains modernize the SARSAT components that are vulnerable and that are being migrated to a new Virtual Private Network solution.

- Work has been completed on activities that dealt with ESPC, SARSAT, and GOES to document, implement, and monitor secure configuration baselines. However, work remains on the recommendation to integrate these improvements as part of an ongoing project for upgrade of the POES system components. This is a phased effort consisting of an initial planning phase expected to conclude by the 2Q FY 2017, followed by an implementation phase based on the plan developed under the initial phase.

PTO Telework

During fiscal year 2014, serious management concerns came to light in two Inspector General reports, including one titled "Review of Waste and Mismanagement at the Patent Trial and Appeal Board," and a PTO Internal Administrative Inquiry Report in response to an Inspector General Referral. In 2015, The National Academy of Public Administration issued its report entitled "The United States Patent and Trademark Office: A Telework Internal Control and Program Review."

Question: How has the PTO addressed mismanagement identified in the 2014 IG reports? What steps does PTO plan to take to continue addressing these issues?

Answer: "Review of Waste and Mismanagement at the Patent Trial and Appeal Board"

On July 28, 2014, the USPTO received the Department of Commerce's Office of Inspector General's (OIG) Investigative Report No. 13-1077, "Review of Waste and Mismanagement at the Patent Trial and Appeal Board," regarding Patent Trial and Appeal Board (PTAB) paralegals who had insufficient workloads and considerable idle time during work hours. On October 10, 2014, the USPTO timely responded to the OIG's findings and nine recommendations, outlining the measures the Agency had taken and would take to ensure all PTAB employees have sufficient workloads. The Agency then worked closely with the OIG to address the IG's recommendations.

Specifically, the Agency has taken the following measures to address the OIG's findings:

- Engaged an internal oversight team of senior USPTO leaders to assist the PTAB in identifying, analyzing, and correcting PTAB staffing issues;
- Retained a management consultant to recommend more efficient workflow procedures to avoid workload problems going forward, including procedures related to Paralegal Specialist resources, and development of a more robust staffing model to predict and support appropriate staffing levels, which the PTAB has now instituted;
- Created and filled a permanent Senior Executive Service (SES)-level Board Executive position to oversee development and improvement of PTAB operations and support services, including the Paralegal Specialists;
- Streamlined its management structure of the Paralegal Specialists and reorganized the manner in which work is assigned to Paralegal Specialists to improve workflow and increase flexibility in work assignments;
- Consistently assigned work to all Paralegal Specialists, and reinforced for Paralegal Specialists and their supervisors the instructions for requesting additional work when needed;
- Negotiated a Memorandum of Understanding with the union representing the Paralegal Specialists to guarantee that the union will notify management if they learn of Paralegal Specialists with insufficient workloads, which allows for immediate assignment of work;
- Strengthened training to PTAB employees, including Paralegal Specialists, on teleworking policies and procedures and "best practices" for effective telework, as well as the appropriate use of the PTAB time codes; and
- Provided training to PTAB employees on the importance of and obligation to disclose waste, fraud, abuse, and mismanagement to appropriate authorities, including the OIG.

The PTAB workforce is now fully occupied. The Board continues to closely and consistently monitor PTAB Paralegal Specialist workloads, including a regular review of Paralegal Specialist production statistics, to avoid and correct any inconsistencies in

Paralegal Specialists' workloads. Moreover, PTAB now also relies on alternative staffing authorities (e.g., details and temporary hires) to address temporary increases in workload.

USPTO Internal Administrative Inquiry Report responding to Inspector General Referral No. 12-1196-H

On July 9, 2013, the USPTO transmitted its Internal Administrative Inquiry Report to the Office of Inspector General in response to the Inspector General Referral No. 12-1196-H regarding allegations of abuse of the Patents telework program at the USPTO.

USPTO's senior managers aggressively responded by implementing the recommendations in the Internal Administrative Inquiry Report and a number of additional improvements to help preclude any potentially abusive behavior in the future. Teams of employees from across the Agency were formed and worked together to explore more effective methods for the early intervention and prevention of telework-related and time-and-attendance-related problems, as well as the enforcement of telework guidelines when problems occur. These efforts have resulted in the following Agency initiatives:

- As referenced in the question below, the Agency retained the National Academy of Public Administration (NAPA) to conduct a thorough and independent evaluation of the Agency's telework programs. This evaluation included an internal control review and programmatic review of the effectiveness and efficiency of the USPTO telework programs, focusing primarily on the Patent teleworking programs;

- Instituted mandatory annual training in FY2015 on time and attendance, work schedules, leave, and overtime policies for all Patent employees;
- Improved Patents management training on time and attendance, work schedules, leave, and overtime policies and procedures based on feedback gathered from supervisors;
- Expanded the telework awareness campaign to include additional outreach to Patents teleworkers including dissemination of teleworking best practices;
- Improved management handling of conduct issues in the current performance appraisal plan Agency-wide;
- Patents revised its policy for obtaining and using Agency records, including computer usage records, to help verify claims of time and attendance abuse cases and developed processes for reviewing and using these records resulting in a consistent Agency-wide policy;
- Patents identified major types of misconduct and their root causes and developed guidance and training for all Patents supervisors on preventative measures;
- Created an Agency-wide Workforce Management Alliance to outline the Agency's vision to maintain productive employee-management relationships and provide an ongoing community of interest focused on addressing employee-management relationships;

- Implemented a new Agency-wide policy for fulltime teleworkers and supervisors in February 2015 to reinforce the importance of work schedule notification, communication, and collaboration among employees and supervisors, especially as the USPTO workforce increasingly migrates away from the Alexandria headquarters through fulltime telework programs and the opening of regional satellite offices.

Question: How has PTO addressed the recommendations of the National Academy of Public Administration? What recommendations remain to be addressed?

The USPTO addressed the 23 recommendations in the July 2015 NAPA Report and took a series of actions resulting in significant strides towards improving telework operations and management enterprise-wide. The Agency's responsive actions are outlined below.

- Developed a computer-based training that will be required of all teleworkers that contains important information on telework duties and responsibilities, reiterates best practices, and requires teleworkers to review their specific telework guidelines. The training is expected to launch in November 2016.
- Evaluated telework guidelines across all business units (bargaining and non-bargaining employees) as well as developed a telework guidelines roadmap and a standard telework guidelines template.
- Administered a standard operating procedure to input employee separation data into the telework database to ensure accurate tracking of teleworkers. Created an in-house report to address the reporting issue when pulling data for employees who separate from USPTO but transfer to another agency within DOC.
- Evaluated the overtime approval procedure. Based on the evaluation, USPTO is currently developing a policy to require non-production employees to leverage WebTA for overtime requests.
- Evaluated how Patents grants authority to work overtime and developed a series of recommendations based off of the review, including communicating existing policy and procedure to all supervisors. Management was advised to consider potential union negotiations before adopting and/or implementing any recommendations to impose additional limitations on overtime availability.
- Researched the use of other supporting collaboration tools such as an online team meeting calendar.
- Deployed a series of initiatives focused on improving communication between supervisors and employees, including management handbooks on telework, "Telework Tune Ups" for business units, and telework training for new managers.
- Conducted Supervisory Patent Examiner (SPE) focus sessions and, based on the outcome of these sessions, trained SPEs on their responsibilities regarding time and attendance and employee relations policies (which will be repeated annually), provided updated guidance on certification of time and attendance records, and developed a training involving frequent time and attendance scenarios and responses to ensure SPEs are prepared to handle situations.

- Administered additional supervisor training on managing in a distributed work environment, and time and attendance.
- Developed Patents and Trademark guidance to detect early warnings of time and attendance problems. The guidance clarifies that a concern may be raised if the amount of work produced is inconsistent with the hours claimed.
- Conducted an evaluation of the Employee Relations (ER) office to find out if there are any bottlenecks or other impediments to providing more timely responses to supervisor requests. The Agency brought on additional ER Specialists in FY 2016 and an additional ER Specialist will be brought on in FY 2017.
- Implemented an internal analysis concerning the performance of fulltime teleworkers and the existence of any barriers that may prevent Patents supervisors from effectively assisting Examiners remotely. Conducted a performance analysis of fulltime teleworkers versus non-fulltime teleworkers from FY 2013 to FY 2015 and concluded that fulltime teleworkers should continue to receive fewer performance warnings from year to year. This data did not support the need for requiring a probationary telework period for fulltime teleworkers or for requiring underperforming teleworkers to return to headquarters. However, Patents recognizes, and is taking advantage of, the inherent advantages and benefits that result from occasional in-person training events including enhanced collaboration, learning, morale, and employee engagement.
- Addressed the recommendations outside the scope of the NAPA telework internal control and program review, including: continuing to review the Docket Management element of the Examiner performance appraisal to ensure the right balance between quality and pendency; continuing to monitor the returning of cases to Examiners to correct errors; implementing the USPTO Quality Initiative focused on excellence in work products, measuring patent quality, and customer service; initiating an in-depth review of Examiner production standards; and increasing collaboration among Examiners and with other countries to improve the quality of prior art searches.

The Agency continues to evaluate some of the remaining NAPA recommendations, including:

- NAPA recommended that the USPTO consolidate, align and refine all existing telework agreements, addendums, memorandums, policies and all other written documentation added to them. While the Agency has extensively evaluated the various telework guidelines across the Agency, consolidating, aligning and refining any telework agreement negotiated with one of the Agency's three unions will require additional negotiation.
- NAPA recommended that all employees provide advanced notice of the hours they work on a given day and to use an on-line collaboration tool while working. While fulltime teleworkers have been required to provide advance notification of their work schedules and remain logged into the Agency's collaboration tool since February 2015, expanding these requirements to all employees continues to be discussed with the unions.

Question: What steps has PTO taken to ensure that employee time and attendance is appropriately managed and that nepotism is not tolerated? What additional steps is PTO planning for the future?

Answer: The Agency's responsive actions to the Internal Administrative Inquiry Report on the Patents telework program and the 2015 NAPA recommendations have enhanced the Agency's time and attendance management. Moreover, the Agency anticipates continuing many of these management activities going forward. The Agency's efforts to effectively manage time and attendance include:

- Mandatory training for all Patents employees on time and attendance, work schedules, leave, and overtime policies and procedures;
- Improved Patents management training on time and attendance, work schedules, leave, and overtime policies and procedures;
- Revised Patents' use of Agency records, including computer usage records, to help verify claims of time and attendance abuse cases;
- Provided updated Patents management guidance on certification of time and attendance records;
- Implemented a new Agency-wide policy for fulltime teleworkers and supervisors to reinforce the importance of work schedule notification, communication, and collaboration among employees and supervisors;

- Instituted new guidance for Trademark management on certifying time and attendance; and
- Initiated discussions with the Agency's unions to expand work schedule notification requirements for employees experiencing performance and conduct issues.

With regard to avoiding any nepotism in employment actions at the USPTO, the Agency continues to train all supervisors and individuals involved in hiring on the prohibition against nepotism in the hiring process, and more generally trained on compliance with hiring laws, regulations and policy. Since 2014, the Agency has undertaken the following actions to avoid nepotism in our hiring actions:

- The Agency developed a mandatory Hiring Practices and Nepotism training program ("Participating in the Hiring Process - Understanding Ethical Requirements and the role of the Merit Systems Principles") which was presented live on multiple dates between August 2014 and March 2015 to all USPTO supervisors and individuals involved in the hiring process. The training program focused on prohibited personnel practices and nepotism. This training will be offered again during the biennial USPTO Leadership Forum this year, which is required for all USPTO supervisors.
- On November 4, 2014, the Agency issued a policy statement, entitled "Avoiding Prohibited Hiring Practices and Nepotism," establishing the USPTO nepotism

policy that goes beyond current legal requirements and provides ethical guidance concerning employment and other personnel actions affecting relatives and other individuals in close relationships with public officials of the USPTO.

- The USPTO retained a Human Resources consultant to review and audit its excepted service hiring practices. The consultant found that the Agency's practices were sound and identified opportunities to strengthen these practices, which USPTO implemented. For example, the USPTO streamlined its processes to document and record the excepted service attorney hiring lifecycle used within each Business Unit; created hiring templates and standard forms; and developed more consistent applicant screening methods to ensure efficient and effective excepted service hiring across the Agency.
- The USPTO has made accessible to all employees an on-line training module relating to hiring practices and nepotism, which all supervisors must take each year.
- Under the Second Open Government National Action Plan, dated Dec. 5, 2013, all agencies are required to complete Office of Special Counsel (OSC) certification. As part of this certification program, the USPTO has committed to training all supervisors on the Whistleblower Protection Act and the Whistleblower Protection Enhancement Act every 3 years. The Agency completed its first round of required training in August 2015. This training includes information about all 13 prohibited personnel practices, including the prohibition on appointing, employing, promoting, advancing or advocating for a relative. The Agency received OSC certification in December 2015.

The Honorable Robert B. Aderholt
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the Department of Commerce
FY 2017 Budget Request

1. **Question:** I recently enjoyed joining NOAA officials at the SWIRLL (Severe Weather Institute - Radar & Lightning Laboratories) facility at the University of Alabama, Huntsville for the kick-off of the VORTEX-SE field operations. It was a great opportunity to highlight the wonderful work of UAH and their outstanding scientists.

In the final FY16 appropriations bill, the Committee provided $5 million for the VORTEX SE to study the regionally-unique factors that contribute to the formation of tornados and associated severe weather in the Southeast. It received $5.5 million in FY15. The goal is to better understand the formation and characteristics of severe

weather in order to provide better warnings for southeast residents and save more lives and property.

As we all know, the conditions, variables, topography, humidity are all different in the Southeast. With the expertise and extensive infrastructure that is already in place at universities such as UAH, why has the President's budget request zeroed out the VORTEX-SE account? Now is the time to build on these foundations, not cut off these funds.

Answer: In FY 2016, NOAA conducted an observational field campaign (March – April 2016) on the atmospheric properties and thunderstorm activity associated with tornadoes and will also award approximately $2.9 million in competitive grants through the VORTEX-SE program to continue improving our understanding of tornado development and risks in the Southeast. This work is important, and we believe that the two years currently devoted to the study will provide a wealth of regionally-specific information that will yield significant results. A two year study allows NOAA to conduct an initial exploration of the various factors in this targeted research project, and we will reassess the need for further research in this area once the data from this study are fully analyzed. In addition, NOAA will hold a workshop in the fall 2016 that will help inform future research efforts.

NOAA also will continue to conduct weather research that will benefit the Southeast United States. One example of a new initiative proposed for FY 2017 is to develop expertise in mid-range forecasting (3-4 weeks), which will ultimately allow for 30 day weather and water outlooks and improved severe storm outlooks.

NOAA realizes the importance of improving tornado forecasting in the Southeastern, United States and is committed to carrying out the research necessary to make these improvements possible. Through VORTEX-SE, NOAA laboratories and partners are conducting numerous research projects to understand how environmental factors characteristic of the southeastern United States affect the formation, intensity, structure, and path of tornadoes in this region, to determine the best methods for communicating forecast uncertainty related to these events to the public, and to evaluate public response. Moreover, NOAA is coordinating with other agencies to research these issues, including the National Science Foundation.

2. **Question:** The Administration's commitment to clearing spectrum in the 1755-1780 MHz band contributed to a highly successful AWS-3 auction in 2015. Given that mobile data traffic is expected to grow by a factor of six over the next five years, please detail the steps that are being taken by the Department to make more of this "beachfront" spectrum below 2 GHz available for commercial use over that same five

year period. To the extent there are barriers to achieving this objective, please detail what those impediments include and what NTIA is doing to address them.

Answer: Recognizing the constantly increasing commercial demand for spectrum, President Obama in 2010 tasked the National Telecommunications and Information Administration (NTIA) to collaborate with the Federal Communications Commission (FCC) to make available, through either exclusive use or shared access by commercial and government users, a total of 500 megahertz of federal and non-federal spectrum by the year 2020 suitable for both mobile and fixed, licensed or unlicensed, wireless broadband technologies. To date, the Obama Administration has made245 megahertz available for commercial wireless broadband services.

Historically, the commercial wireless industry has prioritized lower band spectrum, at different times identified as spectrum bands below 3 gigahertz (GHz) or 6 GHz, as most desirable for commercial wireless broadband due to its capability to support signals traveling significant distances and penetrating buildings. More recently, however, as the industry looks toward deployment of fifth generation (5G) wireless services, its advocacy has placed greater emphasis on very high frequency spectrum bands that are capable of carrying massive amounts of data traffic. More generally, it has become widely accepted that a modern and future proof commercial network must be supported by low, middle and high band spectrum – each of which serves different needs.

NTIA and the FCC are responding accordingly by continuing to work aggressively to make additional spectrum available for wireless broadband, including on both licensed and unlicensed bases, and for exclusive and shared use both below and above 6 GHz.

Only last year the FCC completed the very successful auction of frequencies for Advanced Wireless Services (AWS-3) spectrum which relied in significant part on frequencies repurposed from exclusive federal use. The auction grossed in excess of $44 billion to support Congressional priorities such as funding the mobile broadband-based First Responder Network (FirstNet) and deficit reduction. The FCC and NTIA also collaborated to make available 100 megahertz of spectrum at 3.5 GHz for mobile broadband on a shared basis with incumbent federal systems, adopting an innovative licensing and dynamic spectrum access model. Meanwhile, the FCC's ongoing spectrum incentive auction is comprised of prime, low band, 600 MHz spectrum. Finally, the FCC also has a proceeding pending that would make available swaths of spectrum above 24 GHz in the millimeter wave range.

Meanwhile, NTIA, in collaboration with other federal agencies, has overseen a quantitative assessment process in low- and mid-range frequencies. A total of 960 megahertz of spectrum is currently part of that assessment as noted in NTIA's Fifth Interim Progress Report on the Ten-Year Plan and Timetable, available at: https://www.ntia.doc.gov/files/ntia/publications/ntia_5th_interim_progress_report_on_ten-year_timetable_april_2015.pdf.

The Honorable Jamie Herrera Beutler
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Department of Commerce FY 2017 Budget Request

1. **Question:** A frequent barrier for potential small business exporters is access to information, or knowing where to go. Specifically, many businesses are unable to find key information on the export process, including identifying changes in foreign regulations, understanding changes in the export license requirements, or identifying where to target their product/service. What specifically is your Department doing to increase the quality of information regarding the issues mentioned above?

Answer: The Department of Commerce's Bureau of Industry and Security (BIS) and the International Trade Administration (ITA) have managed and will continue to manage export initiatives focusing on outreach activities to address the abovementioned concerns.

BIS has long targeted small- and medium-sized enterprises (SME) for outreach on the requirements and revisions of the Export Administration Regulations (EAR). BIS outreach is intended to facilitate greater awareness and understanding of, and compliance with, the EAR in an effort to alleviate some of the regulatory burdens.

BIS's SME efforts include:

- Establishing, in 2009, a Roundtable at BIS's Annual Update Conference on Export Controls and Policy. The SME Roundtable discussions are consistently well attended events in which SMEs can share their needs and concerns with government representatives.
- Partnering with the Small Business Administration (SBA) to reach SMEs.
- Working with the Association of Small Business Development Centers (ASBDC) to facilitate center counselors' knowledge about export controls so they may provide guidance to their clients.
- In FY 2015, BIS conducted or participated in 51 seminars in the United States. BIS conducted over 350 events for industry, including the free weekly teleconferences on specific Export Control Reform topics, hosted by our Assistant Secretary for Export Administration, Mr. Kevin Wolf. BIS export counseling and outreach staff answered 33,000 telephone and email inquiries, many from SMEs.

- In FY 2016, partnering with the SBA and other SME-focused organizations to provide additional export control training programs aimed at SME exports and compliance.

In the current economy, additional revenue generated by sales into foreign markets is frequently the difference between a small business laying workers off and hiring new ones to help expand their business. Thousands of these small business exporters depend on the Department of Commerce (DOC) and ITA to help them compete and win new business in international markets. This is accomplished by alerting them to new exporting opportunities, assisting them in navigating the complexities of exporting, and compelling other countries to maintain a fair and level playing field for U.S. goods and services. ITA is keenly aware of the challenges facing its small- and medium-sized business customers and is committed to providing them with actionable information that helps them take advantage of more opportunities more quickly.

To meet exporters' increasing need for timely, high-quality information in today's data-rich economy, ITA is implementing world-class commercial platforms that have been successfully adopted by numerous Fortune 500 companies to enable effective and efficient delivery of products, services, and information to small- and medium-sized businesses. ITA is also making data available "wholesale" via third parties such as FedEx, WebPort Global, and 3M, enabling ITA to reach tens of thousands of additional small- and medium-sized businesses without increasing costs to taxpayers. Most importantly, these tools enable the creation of specialized communities for sharing data, effectively making the government a facilitator of information sharing rather than a single gateway to information.

The net effect of this approach is a significant expansion of the information available to customers in one place, more original analysis and granularity of that information, and increased ease of access to that information for exponentially more small- and medium-sized businesses than ITA could otherwise serve.

In addition, ITA is producing sector-specific reports that are designed to help U.S. exporters identify foreign market opportunities, using market intelligence and data to inform decision-making. Each Top Markets Report ranks future export opportunities within a particular industry based on a sector-specific methodology. The reports provide a detailed assessment of the competitiveness landscape within a sector, as well as the opportunities and challenges facing U.S. exporters in key markets. The reports combine the unique expertise of ITA's sector leads in Industry & Analysis with economic data and the views of trade experts stationed around the world. Exporters can currently access through www.trade.gov/topmarkets reports covering 21 sectors, with additional updates and new reports to be released throughout 2016.

ITA has also developed and maintained online tools available to exporters to access country-and industry --specific information. These include the following:

- Export.gov

- TradeStats Express is available to the public for up to date detailed trade data: http://export.gov/tradedata/index.asp.
- STOPFakes is a resource to support SMEs, and large companies in protecting their intellectual property, and enforcing their intellectual property rights abroad. http://www.stopfakes.gov/
- The FTA Tariff Tool is an application that helps companies to identify destinations where there may be opportunities for their products based on Trade Agreement commitments. We continue to look for new ways to provide this information to SME exporters. http://www.export.gov/fta/ftatarifftool/

In the standards area, ITA is partnering with the American National Standards Institute (ANSI), which promotes and facilitates voluntary consensus standards and conformity assessment systems, on a program called Standards Alert that aims at making sure U.S. companies know about new standards development work that could affect their global market access. Under the Standards Alert program, launched in late 2014, ITA standards experts, industry specialists and U.S. Export Assistance Centers work to locate companies that might have an interest in participating in work being launched by international standards development organizations and connect them with ANSI to learn about how to get involved. The program has had some notable impacts, including on the U.S. feed milling machinery industry where our companies, mostly small and medium sized enterprises, found out about a new standards development activity through Standards Alert and are participating to help ensure that our trading partners' regulations incorporating the standard will not impede U.S. global market access."

In addition to the outreach efforts of BIS and ITA, the National Institute of Standards and Technology (NIST) Hollings Manufacturing Extension Partnership (MEP) offers ExporTech, a national export assistance program that helps companies enter or expand in global markets. This program, designed to help small U.S. manufacturers prepare to export their products, is offered jointly with U.S. Export Assistance Centers of the Department's U.S. Commercial Service.

ExporTech is the only national program in which participating companies develop written export plans, which are vetted by a panel of experts upon completion. Working through local MEP Centers across the country, ExporTech efficiently connects companies with a wide range of world-class experts that help navigate the export sales process. Participating companies rapidly expand global sales and save countless hours of effort.

Since 2007, 152 ExporTech programs have been delivered in 31 states to over 800 companies. Seventeen ExporTech sessions are scheduled through the end of calendar year 2016.

On average, companies that have completed the program have achieved the following impacts:

• $500,000 - $700,000 average sales increase/retention per company

• $91,000 average cost and investment savings per company

• $400 Million in total program sales (new/retained) to date

Furthermore, the Standards Information Center within NIST's Standards Coordination Office serves as a starting point to identify information on standards, regulations, conformity assessment and other requirements that impact America's exporters. The Standards Information Center helps U.S. manufacturers and businesses maximize their exports by providing information about national and international standards and regulatory requirements.

NIST's Standards Coordination Office also operates the World Trade Organization (WTO) Technical Barriers to Trade (TBT) Inquiry Point for the U.S. The TBT Inquiry Point maintains Notify U.S., a free, web-based e-mail registration service, which allows U.S. citizens, industries, and organizations to review and comment on proposed foreign technical regulations and conformity assessment procedures. These regulations and procedures can affect U.S. businesses and their access to international markets. Users of Notify U.S. may receive notifications of regulations tailored to their businesses by industry sector and by WTO Member country.

The NIST TBT Inquiry Point:

• Serves over 3,000 active Notify U.S. subscribers, 85% of which are from the private sector

• Distributed over 3,183 new and updated notifications in calendar year 2016, and nearly 25,000 since 2011

• Conveyed comments from US stakeholders on 77 WTO Member country measures in 2016, and over 970 since 2011

The Honorable Steven M. Palazzo
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Department of Commerce FY 2017 Budget Request

Question: The Argos Data Collection and location System (A-DCS) is a unique, worldwide tracking and environmental monitoring program that provides global coverage and platform location by satellite. The Argos program was established under a joint agreement between the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the French Space Agency, Centre National d'Etudes Spatiales (CNES). All programs using Argos must be related in some way to environmental protection and awareness, or to protecting human life. The U.S. Government (notably NOAA) makes up the biggest user of Argos data, accounting

for more than 40 percent of total system users. Additionally, Argos is an important tool in predicting long-term climate and weather trends, and also has countless national security applications.

In order to replenish the severely aging NOAA satellite infrastructure on which Argos relies, NOAA agreed in 2015 to launch new, updated Argos instruments no later than 2019. However, the President's FY 2017 budget for NOAA would DELAY this critical launch until 2021. I fear that this delay leaves the Argos system, and the broader US community of stakeholders who rely on it, at risk for serious gaps in important, long-term data streams.
Please explain why the Department has delayed the 2019 launch of new Argos instruments? If Congress makes funding available to NOAA in FY 2017, can NOAA immediately get back on track to support the 2019 launch?

Answer: The Department changed the Launch Readiness Date from Q4 FY 2019 to Q1 FY 2021 based on an affordability decision not to fund launch services in FY 2017. The Launch Commitment Date and Target Launch Date were left as "To Be Determined" in the FY 2016 Congressional Justification.

During the FY 2017 budget process, the Department of Commerce carefully reviewed all FY 2017 resource requirements and made final funding decisions based on Administration priorities and resource availability. As a result of this process, the FY 2017 President's Budget request did not include launch services funding for Argos in FY 2017, instead recommending $500K in funding that would enable NOAA to complete planning work and reevaluation as a part of the FY 2018 budget process. NOAA and its partners will continue to monitor and manage the health of the Argos constellation to maximize longevity of current assets.

If Congress were to make funding available to NOAA in FY 2017, it is unlikely that a FY 2019 launch would be possible as a result of schedule constraints.

The Honorable Michael M. Honda
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Department of Commerce FY 2017 Budget Request

Question: In what ways does the coastal science program in the National Ocean Service contribute to the forecasting of and response to ecological events like the harmful algal bloom in the Pacific that closed multi-million dollar fisheries for months? How would additional resources for the coastal science program improve forecasts and responses?

Answer: The coastal science program in the National Ocean Service, as executed by the National Centers for Coastal Ocean Science (NCCOS), advances the understanding,

response, and mitigation of cumulative ecological stressors affecting coastal communities and economies. The program comprises both intramural research and competitive research grants. Significant portions of both are devoted to predictive modeling, forecasting, early detection, and prevention of ecological hazards such as harmful algal blooms (HABs) and marine pathogens. Also within NOS, the Integrated Ocean Observing System supports monitoring and early detection, and the Center for Operational Oceanographic Products and Serviced supports operational forecasts. Ecological forecasting is a cross NOAA effort, with contributions from OAR, Fisheries, NWS, and OMAO.

Specifically with respect to HABs, NOAA:

1. Conducts and funds research to:

- understand the causes of HABs, what triggers toxin onset, how toxins are transferred, and assess toxin impacts; and
- assess social and economic impacts of HAB events, and the costs and benefits of mitigation strategies.

2. Enhances HAB monitoring and response by:

- developing and deploying sensors for HAB and toxin early detection and measurement; and
- moving promising HAB technologies from development, to demonstration, and application.

3. Develops and transitions forecasts to operations by demonstrating operational capabilities for forecast models and transitioning validated forecast models to operations.

4. Advances prevention, control and mitigation by developing decision support tools and prevention strategies.

The President's Budget request in FY 2017 includes a program increase request of $4,000,000 for NCCOS Competitive Research. Specific needs in the Pacific coast that could be supported by this increase include:

- CA monitoring and prediction: Expansion and improvement of a predictive model for domoic acid in central California, collection of data to validate the model, and accelerated transition to operations;
- CA research and modeling: Investigation of the cause and impacts of recently discovered freshwater HAB toxins (in addition to marine toxins) in San Francisco Bay and new toxins observed in shellfish in the Pacific Northwest;
- OR and WA monitoring: Advanced warning of HABs in the Pacific Northwest via improved offshore detection of HABs and toxins;

- OR and WA prediction: Weekly bulletins and seasonal HAB and hypoxia forecasts for Pacific Northwest outer coast and Puget Sound; Evaluation of the Pacific Northwest and Puget Sound forecast for possible operationalization; and
- Toxin detection: Acceleration of FDA accreditation for low-cost and accurate tests for paralytic shellfish and other HAB toxins, and training tribal and other coastal communities in their application.

In general, the additional resources requested for the coastal science program will improve forecasts and responses by filling gaps in monitoring and early detection, telling us where HABs are and where they are emerging, and what is triggering blooms and toxicity. That information can be incorporated into models, validated, and transitioned into operational forecasts.

Question: How are results from federally funded marine debris research projects incorporated into improving the marine debris program, including preventing marine debris at its source?

Answer: The NOAA Marine Debris Program (MDP) funds research to improve understanding of the types, sources, and impacts of marine debris in order to inform the program's actions. The MDP selects research topics in a strategic manner to address the priorities of the Marine Debris Act and emergent issues. The results of marine debris research project help the program target removal efforts to specific locations, make informed investment decisions on specific types of prevention projects, identify new technologies, and conduct public outreach more effectively.

Research on marine debris detection and monitoring helps the MDP to identify marine debris hotspots that could benefit from removal activity and targeted prevention activities. The development of standardized methods for detection of different types of debris and for monitoring the abundance and distribution of debris has been essential in the process of creating baseline knowledge on the main types of debris, how marine debris moves, where debris accumulates, and potential sources.

A second priority research topic outlined in the Marine Debris Act is to assess, reduce, and prevent the adverse impacts of marine debris. While many impacts are immediately evident, research is needed to assess less visible impacts so that they can be more effectively mitigated or prevented. For example, research supported by the MDP has identified the chemical interactions of plastic debris with the marine environment, and their effects on marine species and aquatic food chains. This knowledge helps direct prevention activities to focus on plastic debris. NOAA has also supported research on economic sector-specific impacts, such as fishing and recreation, which helps to target outreach messages to communities and industries.

Research on derelict fishing gear has generated the development of alternatives to gear as well as enhancements to tracking and recovery of lost gear. Each type of fishing gear has

different impacts on the marine environment if lost or abandoned. Research supported by the MDP has helped to identify commercial fishing gear types with the largest impacts and has worked to develop technologies to reduce loss, lessen bycatch, and improve recovery of lost gear. An example of a technology is the development of biodegradable escapement panels in crab traps to reduce bycatch when traps are lost.

The results of MDP funded studies are also incorporated into the MDP's robust education and outreach initiative to educate the public about causes and impacts of marine debris and to inspire behavior changes which result in the prevention and reduction of marine debris. The MDP's education and outreach initiative includes direct education and outreach by program staff located in nine coastal regions around the country through school education programs; teacher workshops, outreach and regional events, and engagement with stakeholders; educational displays at National Marine Sanctuaries and National Estuarine Research Reserves; digital communication through the MDP website, blog, monthly e-newsletter, and social media platforms; and educational materials such as Trash Talk.

Question: Last summer, the Department proposed a rule setting export controls on "intrusion software." If finalized, the proposed rule would have hamstrung U.S. technology companies as well as the customers of those products who need protection from hackers. Last December, 119 of my congressional colleagues and I sent a strongly bipartisan letter to National Security Advisor Susan Rice with our concerns and asking her to get personally involved in the rule-making process. In reaction to this letter and the overwhelming public comments citing concern about the proposed rule change regarding 'intrusion software', the Obama Administration announced in late February that it will renegotiate this portion of the Wassenaar Arrangement with the other 41 countries that are part of the agreement. Moving forward, what course of action do you intend to take regarding the Wassenaar Arrangement and 'intrusion software'? How is the Department of Commerce involved with the State Department as it renegotiates this aspect of the agreement? Is the Department of Commerce pushing for complete removal of these controls on intrusion 'technology, software, and systems' or are you seeking a changing of the definition of 'intrusion software' and seeking a reformed rule?

Answer: The network intrusion controls were approved by Wassenaar in December, 2013. At that time, the 41-member multilateral export control group, of which the United States is a member, agreed to implement technical language consistent with national law and regulation. Adjustments to the controls are made on an annual basis.

The initial 2016 discussions on the Wassenaar network intrusion controls took place in mid-April in Vienna, Austria, at which time the U.S. delegation tabled a proposal to eliminate the most problematic provision of the controls language (that dealing with the specific control on technology for the development of intrusion software).

At that meeting, the U.S. delegation presented a summary of concerns voiced by U.S. cybersecurity stakeholders. The meeting also included a wider discussion of Wassenaar controls on hardware, software, and technology for command and delivery platforms for intrusion software.

At the discussions, Commerce worked closely with the delegation representatives of the Departments of State, Defense and Homeland Security, all of which actively supported the Administration's position. In addition to advocating removal of the technology controls, the Administration is considering the rest of the Wassenaar language holistically with the intent of making the control workable for cybersecurity stakeholders while being sensitive to the intent to control the purpose-built malicious software platforms that were the original target of the controls. These discussions will continue into the fall.

THURSDAY, MARCH 3, 2016.

OCEAN WORLDS

WITNESSES

DR. CHARLES ELACHI, DIRECTOR, JET PROPULSION LAB

DR. JONATHAN LUNINE, DIRECTOR, CORNELL CENTER FOR ASTROPHYSICS AND PLANETARY SCIENCE

Mr. CULBERSON. The Appropriations Subcommittee on Commerce, Justice, and Science will come to order. I would like to welcome our two distinguished panelists, Dr. Charles Elachi, the Director of Jet Propulsion Laboratory; and Dr. Jonathan Lunine, the Director of the Cornell Center for Astrophysics and Planetary Science. We are very pleased to have you here with us today to talk about the future of one of the most exciting areas of looking into the future of space exploration, the Ocean Worlds program that this committee put in place in last year's bill to open up new frontiers in the search for life where it will be the most, I think, promising. And we are going to discuss that with you today and I appreciate so much your taking the time to be with us.

I understand Dr. Elachi, we want to keep your testimony to a minimum, because we do not want you to get complete laryngitis. Dr. Elachi is being honored tonight. We want to make sure he has got enough voice for your acceptance speech tonight.

We live in an extraordinary time where the scientific community has revealed to the world that there are as many Earth-like planets as there are stars in the sky. The amazing discoveries that Kepler has made to discover not only Earth-like planets but solar systems everywhere we look and the possibility for life on those other worlds and indeed within our own solar system has become very, very real. So today we are here to talk about that search for life beyond Earth, the search for Earth-like planets, the need to develop next generation rocket propulsion to enable us to reach the outer solar system more rapidly and lay the foundation for interstellar travel so that our children and grandchildren will actually have the reality of being able to reach Alpha Centauri and beyond.

I particularly want to welcome our first witness, Dr. Charles Elachi, the Director of the Jet Propulsion Laboratory who it has been my privilege to know and work with ever since we first met in 2004 at the Mars Opportunity landing in January of that year. Over the years, as I have gotten to know Dr. Elachi and work with him, I have come to see that I think quite frankly that the Jet Propulsion Laboratory is the gold standard for NASA flight centers. The work that you do is extraordinary. The way that Cal Tech and JPL work with NASA is I think a model that I would like to see replicated at other flight centers around the country. Your collaboration with the National Science Foundation and MIT has most re-

cently led to a confirmation of a theory that Albert Einstein came up with a hundred years ago about gravitational waves, something I am looking forward to getting briefed on when I come visit you again in the near future.

The discoveries you have made are just absolutely extraordinary. JPL in particular, NASA has developed with JPL taking the lead and creating mankind's first interplanetary data relay system with the constellation of satellites and landers that you have in place around Mars. And it is just absolutely extraordinary. The Opportunity lander, in fact, that I was there with you in January of 2004, is still thriving and doing well after all these years making great discoveries.

I want to make sure the committee is aware, Dr. Elachi has just announced his retirement. Your successor will be in the same position, I think, that Thomas Jefferson was when he discovered that Benjamin Franklin was retiring as the American Minister to France. Someone asked Mr. Jefferson about replacing Dr. Franklin, and he said, "No one can replace Dr. Franklin. I can only succeed him." And your successor will be in the same position, Dr. Elachi. Your contributions to the country, to the exploration of outer space, and to pushing the frontiers of human knowledge are just absolutely unparalleled and it has been a great privilege for me to get to know you and work with you, and the great team that you have got there at the Jet Propulsion Laboratory. And your successor is also going to have to manage, as you do so beautifully, to pull off not only weaving together all of the scientists, the engineers, but being able to work with elected leadership. And you know you will have the support of this committee. And your successor will have the same level of support that you have always had.

I want to be sure also to welcome and thank Dr. Lunine for being with us today, who is the David C. Duncan Professor in the Physical Sciences and the Director of Cornell's Center for Astrophysics and Planetary Science. And you have a particular interest, I know Dr. Lunine, in how planets form and evolve, what processes maintain and make habitability possible, and what kind of exotic environments might host the chemistry that would be consistent with the evolution of life in one, maybe in the form that we know and perhaps in others. I would be interested to hear your thoughts on that.

We have in our bill, the 2016 appropriations bill and in previous bills, made certain by law that NASA is going to fund and fly the mission to Europa that the planetary decadal survey recommended last decade as a top priority, and then this decade as a priority right there with the Mars cache mission. And we have made that mission a top priority because it is the top priority of the decadal survey but also because it holds the greatest promise for discovering life on another world. And I want to discuss that and how important that mission is and why that moon of Jupiter is the place we will most likely, in your opinion, find life on another world in our own backyard.

NASA is uniquely positioned to explore our universe. It is the only government agency that pushes the boundaries of our knowledge by sending humans and machines beyond Earth to explore and discover. NASA's image among the American people is so posi-

tive and so high that the only other function of the government that even comes close to them is the United States Marine Corps in a wonderful nationwide survey that I saw, of when you think about the government which agency of the government has the greatest recognition and positive feeling. It is NASA and the United States Marine Corps.

But unfortunately once again the Office of Management and Budget has given us a 2017 request that cuts the planetary science budget; that cuts NASA below the level funded by this committee and the Senate. Very disappointing and aggravating. It is why we included language in the financial services portion of the bill that makes it clear that the agencies of the Federal government have to follow the appropriations bill and they cannot follow the budget. So it is important for you to communicate to your colleagues that they should just frankly ignore the budget recommendation. Do not be concerned, do not be alarmed by what they read in the budget. Follow what is in the appropriations bill. My good friend Mr. Honda and Mr. Fattah and the members of this subcommittee are going to make sure that we take good care of the scientific community and NASA.

The decadal survey in my mind has always been the gold standard that NASA should follow. They do a superb job of prioritizing missions, having the scientific community experts get together, and decide which missions are the most important and then they prioritize them. And if I could just take a moment before I wrap up and recognize my good friend and ranking member Mr. Honda, the decadal survey for 2013–22 states in relevant part that, "if NASA's planetary budget is augmented then the program will also carry out the first in depth exploration of Jupiter's icy moon, Europa. This moon with its probable vast subsurface ocean sandwiched between a potentially active silicate interior and a highly dynamic surface ice shell, offers one of the most promising extraterrestrial habitable environments in the solar system and a plausible model for habitable environments outside of it. The Jupiter system in which Europa resides hosts an astonishing diversity of phenomenon, illuminating fundamental planetary processes. While Voyager and Galileo taught us much about Europa and the Jupiter system, the relatively primitive instrumentation of these missions and the low volume of data returned left many questions unanswered."

The decadal survey goes on to say, "Major discoveries surely remain to be made. The first step in understanding the potential of the outer solar system as an abode for life is a Europa mission with the goal of confirming the presence of an interior ocean, characterizing the satellite's ice shell, and enabling understanding of its geologic history." My colleagues, Ocean Worlds, and in particular Jupiter's moon Europa, hold many extraordinary discoveries that are yet to be made. We now know of course about the ocean of Enceladus, and we want to be sure we hear a little bit about that as well.

But in particular I would like the witnesses to focus on the importance of the Europa mission and why it is so critical that we go to Europa, and what we are likely to discover there, and what type of launch vehicle we want to use.

But before we proceed I would like to recognize my good friend Mr. Honda for any remarks that he would like to make.

Mr. HONDA. Thank you, Mr. Chairman. And can you be a little bit more excited about this hearing, please? You can tell. It is just like Christmas Eve.

I want to thank you, Mr. Chairman, and thank you, Dr. Elachi, and Dr. Lunine for joining us this morning to testify on this very exciting topic. And it is really an amazing time to be alive.

We are living for the first time in human history where we have the technological ability to actually seek out and find signs of life beyond Earth, and it is like science fiction. And here we are today actually discussing the NASA missions that will do just that. It is truly inspiring. And from the hundreds and hundreds of planets around distant stars discovered by the Kepler telescope, to the discovery of flowing waters down a crater on Mars, to the discovery of the prevalence of liquid water on at least half a dozen of the moons of Jupiter and Saturn, the last decade has been filled with tantalizing scientific discoveries that are screaming for astrobiologists to go exploring. It sort of sets the stage for that movie "The Martian". And that is exactly what we are going to be doing.

Second perhaps only to my chairman is my excitement for NASA to forage out into our outer solar system and begin a series of missions to explore the water covered moons of Jupiter and Saturn, the so-called Ocean Worlds, and seek out the signs of life. It is time to have missions that are dedicated to searching for the clues and signs of life that may have evolved in these alien worlds.

Missions to Jupiter's Europa are just the first steps. Saturn's moons of Enceladus and Titan are also calling out to us as we search for life beyond Earth and seek to understand the potentially habitable environments of other worlds. And we are not talking about a one and done Europa mission, but instead a series of missions to the Ocean Worlds to probe their environments to see if it is habitable and potentially harbors signs of life. The extreme diversity and resilience of life on Earth has shown us that wherever there is water, organic compounds, and energy, there is life. Each of these Ocean Worlds have these three prerequisites for life and I guess we need to know does this mean life may have developed there? Or do we have neighbors? Or is there more to life forming than just having the ingredients as we understand them today?

I am excited to play witness as we journey out and see what bizarre and magnificent discoveries await us on Europa, Enceladus, Titan, and the Ocean Worlds. And truly for someone like me, who was here before television, when radio was just a crystal, that to go beyond the confines of this planet and watch these kinds of things unfold is really a privilege to be part of this process. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you, Mr. Honda. I feel the same way, as I know Mr. Fattah does. And all of us on the subcommittee are extraordinarily supportive of the work that you do. Dr. Elachi, Dr. Lunine, we are glad to have you with us today. And we will start with you, Dr. Elachi. And of course, without objection, your written statement will be entered into the record in its entirety and we encourage you to summarize, particularly in light of the fact that we

do not want you to lose your voice entirely. But thank you so much for being here, and Dr. Elachi, you are recognized.

Dr. ELACHI. Thank you, and Chairman Culberson, Ranking Member Honda, distinguished members of the subcommittee. Let me start by apologizing about my voice. My doctor's prognosis is that I talk too much. But that is not stopping me, to come and talk to you here. And it is a great honor for me to have this opportunity to talk to you about exploration of life in the Ocean Worlds.

Just thinking about it, that for thousands of years our ancestors looked up into the sky and wondered if there was life. And for the first time in human history, and I will repeat what I said, the first time in human history we know how to do that. We have the technology and the capability to explore for life in our solar system and beyond. And it really depends on us. It depends on you as our leaders and policy makers, and it depends on us as the technical people, we at NASA, in academia, and in industry.

In addition we know where to look, and I am going to touch on two locations and my friend and colleague Professional Lunine will touch on two other locations. First let me talk briefly about Mars. With Spirit, Opportunity, Curiosity and the spacecraft we have in orbit, we are convinced now on scientific grounds that actually there used to be oceans on Mars in the past. And then with the changes of the climate on Mars, the water is frozen now. And the key question is always the ocean in the past. And based on Curiosity's measurement, Mars has all of the ingredients that exist on Earth, could life exist? And that is what we are doing through our Mars program, looking for past life, on Mars.

And as you know we have Mars 2020, which is preparing with biological instruments to look and collect samples so they can be brought back to Earth in the following decade. And NASA in the budget has something that was called Mars precursors, which basically is to prepare for that era. To have the orbiting satellites that are needed and to look at how do we bring those caches back, how do we explore and prospect for ice in preparation for a human mission?

As was mentioned about "The Martian," one thing I like about "The Martian," that that could happen during my children's lifetime. And NASA is putting in place all of the elements which could enable us to explore, that planet.

Now the reason we are in such a good shape in Mars is because NASA developed a well thought-out integrated program, and that is the kind of program we need to do the exploration of the Ocean World, in the outer solar system. Now based on Voyager and Galileo data, we do know that Europa has an ice shell, H_2O ice, it is water ice, like I am drinking here. And it has an ocean below the surface which has enough water, which is two to three times the water which is on Earth here. Now you would say how could that be? It is so cold out there. How could there be liquid water in that location? Well it turned out as these satellites, like Europa, go around Jupiter, which is a very heavy planet, it is about 300 times the mass of Earth, it creates tides exactly like what happens with our Moon. So over millions of years that tide has been pumping that ice back and forth, and that is what leads to generation of heat. So there it has the right ingredient, where you have liquid

water today. It had organic material, and there is energy coming from the tide. So it has all the ingredients that life could exist today. Not in the past.

Now in order to successfully look at that life I think we need basically to land on the surface, melt our way, and get down to that ocean. Now we cannot do that today because there are a number of things that we need to learn before we can do that ultimate mission. So in order to be successful I think there are three elements that need to be done in the near future. One is to have an orbiter which will map the surface of Europa at very high resolution and sound through that ice so we can determine how thick it is. And that is what NASA is planning, a Europa mission that through your direction, NASA and the decadal, NASA today has instruments selected, we are in phase A, and I think we are progressing, with that mission.

The second element is to put a modest lander on the surface so we can determine the characteristics of that ice. So between the combination of the sounding which tells us how thick and the lander which tells us the characteristics of that ice that will prepare us in the future to put a Europa ocean explorer to melt our way and go below the surface.

NASA has started that activity based on your direction. Just a couple of days ago they requested from the science community for people who are interested to be on a science definition team to work with us on defining scientifically what should be the payload. And that lander will capitalize very heavily on what we have done on Spirit, Opportunity, and Curiosity in the technological technique of how do we land with a sky crane. And it looked very much like some of that technology that we have developed before. So we are very confident technologically that with appropriate funding that mission could be done at an acceptable risk.

And the third element is to have a technology program which will support from now, start to think how do we melt our way, how do we create a submarine? So by having these three elements, I am confident that we can explore the oceans of Europa in the foreseeable future.

Now the next key question is how do you launch it? How do you get there? And here there are a number of possibilities we are looking at. Clearly today we have heavy launch vehicles. Those heavy launch vehicles would take at least seven to eight years to get us to Jupiter. And that is what happened on Cassini. What we have to do is to launch, do a series of fly-bys by Earth to get enough energy to get there. Fortunately NASA is developing the SLS. With the capability of the SLS we can get directly to Jupiter in about two and a half years. That is a huge difference, and to some extent cost saving from the point of view of operation. And then you can have combination. Depending on how heavy the lander is if we cannot go direct we can go and do one fly-by by Earth and then head to Jupiter and that takes about four years.

So as we speak today we are looking at all these different options. Now fortunately what is elegant about our approach is you do not have to wait to decide what launch vehicle and when until another 2 or 3 years. So we can move ahead on the development of the orbiter and the lander and then over the next 2 to 3 years,

as we know the availability of these launch vehicles, their cost, then we can work with NASA, I am sure they will come to you, with what is the right combination of SLS and the traditional launch vehicle.

So let me close by a quote that I would like to mention from President Teddy Roosevelt, because such a program is challenging. We are going to have successes and we are going to have failures. But mentioning, let me repeat, and I am quoting what he said it is "far better to do mighty things, to win glorious triumphs even though checkered by failure, than to rank with those timid spirits that know neither victory nor defeat." The exploration of the Ocean Worlds is one of the mightier things that our country can do and we sure are not going to be timid. Thank you very much.

[The information follows:]

Hearing of the House Appropriations Committee
Sub-Committee on Commerce, Justice and Science

Ocean Worlds Hearing

Testimony submitted by
Dr. Charles Elachi
Director, Jet Propulsion Laboratory
March 3, 2016

Chairman Culberson, Acting Ranking Member Honda, and distinguished members of the Subcommittee, thank you for the opportunity to come before you to discuss the exciting science and mission opportunities for exploring the Ocean Worlds of our solar system.

The search for life beyond Earth is one of humanity's oldest, most profound, and yet unanswered questions. Long before Einstein conceived of gravity waves, long before Higgs conceived of the Higgs boson, long before Watson and Crick discovered DNA, our ancestors were looking up at the night sky wondering if life exists beyond Earth.

We do not yet know whether we are alone in the universe, or if our universe is teeming with life. For the first time in human history, however, we now have the tools and technology needed to answer this age old question. Let me emphasize this point again – **for the first time in human history we have the tools and technology needed to search for, and potentially find life beyond Earth**. We can build the spacecraft and instruments needed to search for life in our solar system and beyond.

In addition, we know exactly where to look: along with the planet Mars, we now know of several moons in the outer solar system that likely harbor liquid water oceans and which could support life as we know it. NASA's search for life beyond Earth has long been guided by the mantra of 'follow the water'. We now know that vast quantities of liquid water reside within many moons of the outer solar system. These moons, these worlds – these **Ocean Worlds**, if you will - are quite likely the best places within our Solar System to find life that is alive today – life that we could someday directly observe: living, thriving, possibly even swimming in these distant oceans.

A critical achievement of NASA's program for the robotic exploration of the solar system is that we now have strong evidence for these oceans of liquid water trapped beneath the icy shells of moons in the outer solar system. These Ocean Worlds are Jupiter's moons, Europa, Ganymede, and Callisto; and Saturn's moons Enceladus and Titan. It may even be that Neptune's curious moon Triton harbors a liquid water and ammonia-rich ocean beneath its icy shell. As we continue our exploration we may find that the giant asteroid Ceres, and the dwarf planet Pluto may also join the list of potential ocean worlds. Taken all together the volume of liquid water in these oceans could be well **over 20 times** the total volume of liquid water found on Earth.

Today I will highlight just three of these moons: Jupiter's moon Europa, and Saturn's moons Enceladus, and Titan. But before I detail those worlds, I should provide some context for what we think it takes for a world to be habitable. That context is best provided by our own planet, our own ocean world, Earth.

Importantly, our study of life on Earth has served as a guide for where to look for habitable environments beyond Earth. Over the course of the past 54 years of NASA's exploration of our solar system we have also learned much about life on Earth and what it takes for life to survive. Microbial life on Earth can survive and grow throughout an incredible range of conditions – from the hottest springs in Yellowstone National Park, to the deepest depths of our ocean, to the driest, coldest valleys of Antarctica – microbial life finds a way.

Life on Earth finds a way - we have learned – in just about any location on our planet where liquid water, the elements for building life, and some form of energy from the Sun, or chemistry from the rocks, comes together. In other words, **the keystones for life are water, elements, and energy**. Wherever we find these keystones together on Earth, we generally find life. We predict that, if these keystones are brought together on distant worlds, we may also find life.

Let me give you one beautiful example of how this works on Earth. In the spring of 1977 my colleague oceanographer Bob Ballard was part of the team that discovered hot springs in the deep dark depths of our ocean. Around those hot springs – which are often referred to as hydrothermal vents – Bob and the team discovered a thriving ecosystem of bizarre red tube worms, eel-like fish, bright white crabs, and an assortment of microbial communities. How could such an ecosystem exist? The Sun does not shine down to those depths. What makes life possible in such an extreme environment? As scientists began to study these vents the answer became clear. The microbes that serve as the base of the food chain are eating the compounds erupting out of the vents – they are doing what we call chemosynthesis, using the chemical energy of materials coming out of the vents. The fish and tubeworms and larger creatures then eat the microbes. The hydrothermal vents bring together the water, elements, and energy needed for life to exist – the energy comes from the rich chemistry of the vents. This is much different from the base of the food chain that we experience around us – where photosynthesis rules the day and the energy to power life comes from our Sun.

The discovery of life around hydrothermal vents at the bottom of our own ocean provides a key bridge to the potential habitability of ocean worlds beyond Earth, which brings us back to the ocean worlds of the outer solar system. Let me begin with Europa.

Europa, the second of Jupiter's four large moons, is about the size of our Moon, but it orbits Jupiter, which is some 318 times as massive as the Earth. The tidal tug-and-pull that Europa experiences as it orbits Jupiter creates the energy needed to maintain liquid water beneath Europa's icy shell. To the best of our knowledge, Europa's ocean is global and it is approximately 60 miles deep; that is **roughly ten times as deep as the Mariana Trench**, the deepest point in our own ocean. The total volume of liquid water within Europa's ocean is **two to three times the volume of all the liquid water in Earth's oceans**.

To reach that ocean – to someday explore that distant sea with highly capable and instrumented robots that can send back images and data – we need to develop a well-defined and systematic approach for exploring the Ocean Worlds.

We will make progress toward this goal with the Europa mission currently in formulation, which will fly past Europa approximately 45 times as it orbits Jupiter. The instrument payload for the Europa mission is already selected and the spacecraft is under development for a launch in the 2020s. With each flyby of Europa, the spacecraft will collect images and return data about Europa's surface

composition, structure and thickness of the ice shell. This mission also has the capability to do the type of reconnaissance necessary for finding landing sites for a potential future lander.

Recently, we at JPL have completed initial studies for landers that would go down to Europa's surface and directly sample and analyze material on Europa's surface. We presented these architectures to NASA Headquarters in February, and are in the process of conducting additional studies to refine the requirements for a potential lander over the next several months. We note that any increase in scope to the current multiply flyby mission likely would add significant cost, schedule risk and complexity.

Of course, having a mission on the launch pad is a lot different than having it at the destination. The rocket that is used to send spacecraft to their destinations is a key part of the process. Future large rockets, such as the Space Launch System (SLS) or, though not in same class as the SLS, the commercial Falcon Heavy, now in development, and existing Delta IV Heavy could help to carry a large payload or reduce the time it takes to reach the outer planets. One concern, however, is the cost of these rockets, which is not known but likely to be significant.

Right now the *Cassini* spacecraft is orbiting Saturn, flying by Saturn's moons and returning data that is revolutionizing our understanding of the Saturnian system. A key discovery of the *Cassini* mission is that Saturn's curious little moon Enceladus – which is only 300 miles across – has an ocean beneath its icy shell. That ocean is jetting out through cracks in the ice shell, creating plumes of water that the *Cassini* spacecraft has flown through and sampled with its instruments conceived in the early 90s but not designed to chemically characterize such an environment. Within those plumes of water we have also found salts, organic compounds, and silica – all of which point toward a salty subsurface ocean that has an active seafloor, with hydrothermal vents that could possibly support life.

The case for Saturn's moon Titan is similar. Titan is a world full of organic molecules, which are of course key building blocks for life. Clouds in Titan's atmosphere rain out liquid methane and ethane, which then collects into lakes that dot Titan's earthlike landscape. Some of these lakes are comparable in size to the Great Lakes that define much of our border to the north with Canada. On Earth, however, our lakes are carved into rock, whereas on Titan the lakes of methane and ethane are carved into a shell of water ice. Beneath Titan's icy shell may reside a global liquid water ocean. Could life have arisen on such a world? For many in the planetary science community Titan is heralded as the place to go to look for 'weird life' – life unlike life as we know it; life that may have originated in liquid methane instead of liquid water. Titan is a totally new frontier for organic chemistry.

Because of these discoveries and great potential for new ones, NASA has added Enceladus and Titan as potential targets for the upcoming call for New Frontiers missions.

An ocean worlds program provides the necessary framework for the systematic exploration of these worlds that may harbor life beyond Earth. Importantly, there is a win-win for exploring, mapping, and making discoveries within our own ocean here on Earth. The tools and technologies for exploring oceans beyond Earth will first be tested and utilized in our own ocean, making scientific discoveries along the way. The physics, chemistry, and biology of our own ocean is the bridge to understanding and exploring oceans elsewhere.

I would like to finish by simply stating that the exploration program I have just outlined – the exploration of Ocean Worlds – will not be easy. There will be failures and successes as we march down this path of discovery. But here is where I find inspiration in the words of that visionary leader, President Teddy Roosevelt. Each day when I walk into my office I see his words displayed in the entryway of my building. The words are simply 'Dare Mighty Things'. In a speech in 1899, Teddy Roosevelt proclaimed that it is "far better to dare mighty things, to win glorious triumphs even though checkered by failure, than to rank with those timid spirits…" This sentiment, "To Dare Mighty Things," has become a clarion call for what we do at JPL and NASA. We want to dare mighty things, and we want to lead this country on the next grand voyage. We are a nation of explorers and innovators and the exploration of Ocean Worlds – on Earth and beyond – is a new great frontier.

Mr. CULBERSON. Thank you, Dr. Elachi. Dr. Lunine.

Dr. LUNINE. Thank you, Chairman Culberson, Ranking Member Honda, and members of the subcommittee. It is a wonderful opportunity to present my views on the search for life in the Ocean Worlds of our solar system but I am going to keep my remarks brief because the chairman and ranking member so well summarized why it is we want to go to each of these worlds.

But I do want to say that I personally feel passionately patriotic and proud of what our nation has accomplished in the exploration of the solar system. And I feel humbled personally to be a scientist participating in one of the greatest space odysseys ever undertaken, the Cassini mission to Saturn. This is an extraordinary voyage of discovery with which I have been involved essentially in the planning stages, when I was a graduate student, up to today. And this mission truly exemplifies the remarkable things that this nation can do, and in particular the remarkable things that the Jet Propulsion Laboratory, ably led by my friend and colleague, has been able to do over the years. These are historic missions and their impact is historic as well.

So both Cassini and its antecedent to Jupiter, the Galileo orbiter, have provided incontrovertible evidence that there are salt water oceans underneath the icy surfaces of three moons of the outer solar system, Europa at Jupiter, Enceladus and Titan at Saturn. And on Titan, Cassini has discovered vast seas of hydrocarbon liquids, methane and ethane, essentially hundreds of times more hydrocarbons than the known gas reserves on the Planet Earth.

Now Dr. Elachi has talked already at length about Europa and so I am not going to discuss that. But I want to make sure that everyone understands that I too find the exploration of Europa and the search for life there a top priority. So I am happy to answer questions about Europa.

But I will press on to Titan, which is larger than the Planet Mercury, the only moon to host a dense atmosphere of nitrogen and methane. Cassini and the European lander that it carried with it, Huygens, have revealed a methane hydrologic cycle, with clouds, rain, river valleys, vast seas, all involving methane and all going on in an unimaginably frigid environment. And yet Titan's surface has all of the formal requirements for life: abundant organics, liquids, and sources of energy. But because that liquid is not water we have to ask the question is this really a place that we want to go look for life? It would have to be very exotic life. But a 2007 National Research Council study in fact said that we should. And it said that Titan is a test for the universality of life as an outcome of cosmic evolution. So if we are going to look for life in those seas, the best way to do that is to land a capsule, float across the surface. That would be the first maritime exploration of an alien sea, which in and of itself would be an extraordinary adventure.

Now let me move on to Enceladus. Enceladus has not surprised scientists; it has completely shocked us. It is a very small moon and yet it has a plume of material pouring out into space from a series of fractures in its south polar region. And it was Cassini that discovered this plume of icy grains and vapor and then flew through that plume seven times, surviving each time. Thanks to the prodigious capability of its instruments, its chemical sniffers,

Cassini has found not only water ice and water vapor, but also organic molecules, salt dissolved in the water, tiny grains of silica, all indicators that inside Enceladus, down in this small, liquid water salty ocean, is a hydrothermal system. A place in which water, organics, and minerals are heated together in the kind of chemical stew that many scientists think was the place where life began on Earth 4 billion years ago.

And there really is a subsurface ocean. Cassini is so powerful in terms of its scientific capability it has detected the presence of the ocean in two completely independent ways. And so if you look at all of the requirements for terrestrial type life, liquid water, organics, minerals, energy, chemical gradients, Enceladus has it all. And all that stuff is pouring out into space. It is not hidden beneath the surface. And so as far as we understand it today Enceladus provides us with the most straightforward way to look for signs of life, given the compelling evidence that much of the gas and the grains are being expelled from the interior ocean.

So let me make this very clear. To sample the plume of Enceladus is to sample the ocean beneath the surface. So merely flying through the plume, as Cassini has done, but with instrumentation more modern then Cassini's, is sufficient to search for signs of life. And this can be done for well below the cost of a flagship mission and it can be done with instruments available for flight today.

So let me summarize by saying that discovering life on or within the Ocean Worlds of our own solar system may provide unexpected and as yet hard to predict practical benefits, something that Carl Sagan pointed out many decades ago. But more profoundly it will inevitably direct our attention to the Milky Way Galaxy beyond the confines of our own planetary system. If life can begin two or three or four times in our own solar system, then the number of planets in the galaxy as a whole that harbor life must be enormously great. And then how could we resist taking the leap beyond our solar system to explore the vast spaces between the stars for life there?

Thank you very much for the opportunity to talk to you today.

[The information follows:]

Statement of

Dr. Jonathan I. Lunine
David C. Duncan Professor in the Physical Sciences
Director, Cornell Center for Astrophysics and Planetary Science
Cornell University

before the
Subcommittee on Commerce, Justice, Science and Related Agencies
U.S. House of Representatives

Chairman Culberson, Ranking Member Honda and Members of the subcommittee,

Thank you for the opportunity to present my views on ocean worlds and the search for life beyond Earth. We live in the most extraordinary of times. When I entered elementary school a half century ago, I was barely aware of the first tentative steps being taken toward exploring the planets—a time when success was measured by the mere survival of the Mariner 2 Venus flyby mission after 5 months in space, or the 21 blurry images Mariner 4 sent back during the first successful flyby of Mars. With the passing of the decades, the perseverance and ingenuity of this nation's engineering talent paid off, as the United States emerged the unparalleled leader in the robotic exploration of the solar system: Voyagers 1 and 2 have been operating in space for nearly 40 years and the US's Mars Reconnaissance Orbiter has returned close to 42,000 images of Mars as of this week.

It is difficult not to feel passionately patriotic and proud of what our nation has accomplished, by itself and together with many international partners, in the exploration of our solar system. I feel humbled to be a scientist participating in one of the greatest space odysseys ever undertaken, the Cassini mission to Saturn. This spacecraft has revealed vast hydrocarbon seas on the surface of Saturn's giant moon Titan, discovered and then penetrated deep into the icy plume of another Saturnian moon Enceladus, finding salt water and carbon-bearing molecules within. It has probed the vertical structure of Saturn's rings, solved the long-standing mystery of Iapetus' white-black dichotomy, discovered mysterious red streaks on the moon Tethys, and found a gigantic hurricane trapped within a bizarre hexagonal wind pattern at Saturn's north pole.

Engineers at NASA's Jet Propulsion Laboratory (JPL) are now preparing Cassini for multiple forays into the narrow realm of space between the innermost ring of Saturn and the planet's atmosphere, before directing it to a fiery plunge into the ringworld on September 15 of next year, after twenty successful years of complex operations in space. Cassini's extraordinary voyage of discovery, as are many other missions such as the Curiosity rover on Mars, is a testament to the extraordinary technological prowess and commitment to success of the engineers and scientists at JPL. They exemplify what makes this nation capable of doing truly extraordinary things.

Cassini, together with its antecedent at Jupiter, the Galileo orbiter, provided compelling evidence for salt water oceans underneath the icy surfaces of three moons of the outer

solar system—Europa at Jupiter, Enceladus and Titan at Saturn. These are the three exemplars of an elite group of "ocean worlds" in the outer solar system. I focus on the three (Europa, Enceladus and Titan) because for them the evidence for liquid water is nearly incontrovertible and we even know something about the compositions of their oceans.

Europa has a very large salt-water ocean in contact with a rocky core, chemical energy associated with Jupiter's radiation belts, and lots of tidal heating-- but we know little else about the prospects for life here. Indeed, we do not know whether organic (carbon-hydrogen) molecules exist within the ocean—but we strongly suspect they are there. Equally important, we do not know how far beneath the moon's surface the ocean lies. Knowing that will allow a strategy to be formulated to search for life there. The Europa Multiple Flyby mission will provide the essential information needed to decide, among other things, whether ocean water is welling up through the cracks, and how to access it. It will tell us whether organic molecules are present. And, should there be plumes or fresh deposits to sample, a sub-probe or lander might access material containing signs of life. We've waited more than 15 years for this mission; it needs to be launched as soon as practicable—ideally by the early 2020's.

Titan is larger than the planet Mercury and is the only moon to host a dense atmosphere of nitrogen and methane. Cassini and the European Space Agency lander Huygens carried by Cassini have revealed a "methane hydrologic cycle" with clouds, rain, river valleys and seas in an unimaginably frigid environment. The surface seas -concentrated in Titan's arctic-- are so vast that they hold hundreds of times more hydrocarbons than do the known oil and gas reserves on planet Earth. And so we cannot avoid asking whether a form of life might have arisen in this exotic environment. Titan's surface has all the formal requirements for life—abundant organics, liquids, and sources of energy. And yet, that liquid is not water—it is methane and ethane. Should we include the seas of Titan in our search for life? As a 2007 National Research Council study[1] noted: "Titan['s seas are] a test for the universality of life as an outcome of cosmic evolution." Beneath the nightmarish landscape of organic rivers and seas, and under perhaps 60 miles of ice crust, is a liquid water ocean. Detected in two different ways by Huygens and Cassini, the ocean must be charged with salts, suggesting that it may have access to an underlying rocky core. This too is a surprise, since models of Titan suggested that any ocean would be perched between two layers of ice, unlike the oceans of Europa and Enceladus. The solar system is, as always, full of surprises.

Because Titan's interior water ocean is so deep, it is probably inaccessible to us. Any future search for life will be difficult. The easiest approach is to drop a floating capsule—a boat-- onto one of the vast surface hydrocarbon seas. It would be the first maritime exploration of an alien sea. Here the complication is that we don't know what kind of biochemistry we are looking for, but a generalized search for patterns in molecular structures and abundances that indicate deviation from the randomness of abiotic chemistry is a good first step.

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[1] The Limits of Organic Life in Planetary Systems, National Research Council, National Academies Press, Washington DC, 2007, p. 74.

Enceladus has not surprised scientists—it has shocked us. It's a small moon and yet it sports a plume of material emanating from a series of fractures in its south polar region. Cassini discovered this plume of icy grains and vapor and has flown into it seven times. Thanks to the prodigious capabilities of its chemical sniffers—mass spectrometers—and other instruments, Cassini has found organic molecules, frozen drops of salty water, and tiny grains of silica—all indicators that inside Enceladus is a hydrothermal system in which water, organics and minerals are heated together in the sort of chemical stew from which life on Earth might have begun. And yes, there really is a subsurface ocean: Cassini has detected its presence in two completely different ways. Make a list of the requirements for terrestrial-type life—liquid water, organics, minerals, energy and chemical gradients—and you find that Enceladus has it all. Conveniently, the evidence is not hidden beneath the surface—it's coming out into space in the plume.

Therefore Enceladus provides us potentially with the most straightforward way to look for life signs, given the compelling evidence that much of the gas and the grains are being expelled from the ocean itself. *To sample the plume of Enceladus is to sample its ocean.* Merely flying through the plume as Cassini has done multiple times, with instrumentation more modern than Cassini's and hence capable of detecting the molecular signposts of life, is sufficient to search for signs of life. It is fair to assume that the basic biochemical building blocks are like those on Earth, since every indication we have from Cassini is that the subsurface ocean would support terrestrial microbes. This can be done for well below the cost of a Flagship mission and it can be done with instruments available for flight today.

The ocean worlds have captured the imagination, not just of planetary scientists and astrobiologists, but of oceanographers, explorers and the general public. Thanks to our nation's investment in the space program—an investment made through the hard-earned wages of every working American—all of humanity can now gaze at Jupiter and Saturn in the night sky and ponder the real possibility that within some of their moons are organisms whose origin was completely separate from life on Earth. What would they be like? Before we can answer this question, we must go back and search these ocean worlds to see if life really does exist in any or all of them.

Discovering life on or within the ocean worlds of our own solar system may provide unexpected and as yet hard to predict practical benefits, as Carl Sagan pointed out many decades ago.[2] But more profoundly, it will inevitably direct our attention to the Milky Way Galaxy beyond the confines of our own planetary system. If life can begin two or three or four times in our own solar system, the number of planets in the Galaxy as a whole harboring life must be very great indeed. And how could we then resist taking the leap beyond our solar system to explore the vast spaces between the stars?

[2] Sagan, C. The Cosmic Connection: An Extraterrestrial Perspective. Doubleday, New York 1973, p. 57.

Mr. CULBERSON. Thank you, Dr. Lunine and Dr. Elachi. And I know my colleagues have questions. It is extraordinary, is it not? We have, the Congress, both Republicans and Democrats alike, strongly supported NASA and its mission. One of the most gratifying things we get to do, is to help you seek out new life and discover these incredible new worlds. And I have, in our bill this year we funded, NASA has the largest appropriation they have ever received since the start of the agency in 1958 and we have got planetary science funded at a level of $1.63 billion this year. What level of funding in your opinion, Dr. Elachi, will be necessary in the 2017 bill to make sure that we stay on track? That the planetary science community has the resources they need to achieve the objectives of the decadal survey, both for this flagship mission to Europa and the new frontiers and Discovery class missions?

Dr. ELACHI. Well I think that is a better question to ask for NASA. But clearly it all depends on when do you want these missions to happen? So from my experience, based on Cassini and other missions, typically it takes us 6 to 7 years after the selection of the payload to actually be ready to be on the launch pad. And in the case of the orbiter or the fly-by, those were selected a year ago. So you can add 6 to 7 years to it. In the case of the lander, it heavily will depend on the payload selection data. So a critical element before we can tell you really the detailed cost is the payload selection.

Mr. CULBERSON. But we are on the right track? This funding level that we are on now, you have got what you need so far?

Dr. ELACHI. Well clearly depending on when you want it. If you want to launch in the early twenties, the present level is not sufficient to do that. I am sure we can provide you with with a more accurate number for it. But I think it is appropriate for NASA now. For the total cost of the mission, as you know, NASA makes a commitment when we do the KDP–C, which is a decision that it makes when we start in the implementation. And those will be coming up in the next couple of years. But we can use as a reference the Cassini mission, or the Mars 2020 mission. Because those are well known missions of similar class to what we are talking about.

Mr. CULBERSON. You know when Neil Armstrong first set foot on the moon, that is an extraordinarily important and important milestone. But the discovery of life on another world I think will be another one of those transformational moments in human history that when that occurs will encourage the entire, it will galvanize the country and the world and certainly encourage the nation to take NASA even further, funding levels that you will need to make sure the American space program is the best in the world. And that is actually another reason I have been so enthusiastic about this mission is that it holds the greatest promise for that first discovery of life on another world which will then enable the entire country to get behind NASA with the funding levels that you need to do what is necessary to keep the American space program the best in the world.

But for this mission to succeed, Dr. Elachi, I wanted to ask you about the launch vehicle. Talk to us, if you could, about the importance of using SLS for the Europa mission. And, can you talk to us a little bit about whether or not it will require one or two SLS

missions? For example, one for the orbiter and one for the lander. Can you talk just a little bit about it?

Dr. ELACHI. Sure. No, I would be glad to address that. As I mentioned earlier with the EELVs, the present launch vehicle, it takes at least 7½ years to get to Jupiter because we have to do a series of fly-bys. With an SLS we can do it in two and half years. And that would lead to, even if SLS might be more expensive, but it would lead to savings of five years of mission operations. So the trade will need to be looked at.

Now we are looking at having the orbiter and the lander as two separate spacecraft. And there are different ways you can launch them. You can put them both on one SLS, but because that will lead to a heavy payload that still will require to do one fly-by by Earth. So that will take us, then it will add one or two years to the mission. Or you can launch them separately on two SLS. And then in that case you can get much faster to Jupiter. So over the next few months at the request of NASA we are going to look at all these different combinations, one SLS, two SLS, EELVs, and provide NASA technically how long it will take us to get there and when would we will be able to land, but also cost-wise, what are the trades. So we should be able to get back to you over the next few months with that trade.

Now as I said earlier we do not need to decide today what launch or what kind of configuration. We can wait about two years before we do that. But no question the SLS or any equivalent there is the Falcon 9 Heavy, will revolutionize how we explore the outer solar system. It will make a huge difference when you send a mission to wait seven years and analyze the data before you plan the next one, versus one where what you have to wait is two years. So no question, the SLS will be a game changer in this area.

Mr. CULBERSON. Thank you. They are going to call votes between about 11:20, I understand, and 11:30, so I want to move on to my—oh, excuse me, 11:30 and 11:50. So we do have a little more time. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman. Dr. Elachi, what are the primary science goals of the Europa orbiter and related missions? And is astrobiology and biomapping part of the stated NASA objectives?

Dr. ELACHI. Let me briefly answer it, but my colleague here is smarter than me when it comes to astrobiology. The orbiter, which has the payload selected already, will do very high resolution mapping of the surface, will look at the composition at the surface with spectrometers, and will allow us to sound through the ice so we can determine how thick is that ice. And with the gravity measurement will be able to determine the characteristic of the ocean, how thick that ocean is. So it will provide us all of the ingredients that are needed to start planning for the next step with the measurements that the lander will get by making in situ measurement of astrobiological components as well as the characteristic of that ice. So let me, with your permission let me turn it to Jonathan. He is smarter than me.

Dr. LUNINE. Well I am not sure I would agree with that statement. But the Europa fly-by mission is very, very well instrumented to address astrobiology goals. And in fact within the orga-

nization of the mission itself we have what is called a habitability working group to look at how these instruments can address those goals. And so there is an instrument that will look for organics on the surface that might have been deposited from the interior. We must understand whether Europa has carbon bearing compounds, organic molecules. We do not know that today and that is a key ingredient for habitability because that is what life as we know it is made of. And there are two instruments, mass spectrometers, that will actually sample Europa material directly on the fly-by spacecraft. If there is a plume, they will sample material in the plume. If not, they will actually sample material that has been deposited on the surface that gets bombarded by micrometeoroids and is then lofted into the atmosphere. And both of those instruments can measure the composition, look for organics as well, and even possibly look for clues that there might be a hydrothermal system in Europa's interior. So I think we are going to get a great deal of information on the habitability of Europa just from the fly-bys themselves, and then a lander of course would provide in situ information to add to that.

Mr. HONDA. OK. So this may be the same question in a different way, though. So if life detection is one of these goals, how will all of this be accomplished by a potential Europa orbiter mission without a secondary mission or landers? And how likely are we to learn something from an orbiter mission that will affect what we would want to know with a lander, both guide where we would want to land and with what type of craft as well as the instruments to put on the lander? And then I understand for decades NASA and JPL have successfully explored planets and their moons through a three-step strategy of fly-by, followed by an orbiter, and then followed by a lander. I have heard this described in your testimony. Each step on this journey builds on the knowledge gained through previous missions, which you have explained. This is designed to maximize the science return at each step while minimizing the scientific and technical risk to spacecraft, landers, and rovers. With respect to a Europa mission concept involving a lander, what provides the confidence that we would know enough about the Europa surface to ensure that a lander will be placed on a scientifically compelling and safe site on the icy surface?

Dr. ELACHI. OK let me——

Mr. HONDA. I know it is a lot of information, but I was just trying to put it all together so I can conceptually understand.

Dr. ELACHI. OK. Now, I think our strategy is the orbiter will get to Jupiter before the lander and it will survey the area, image it at a very high resolution, identify the area of interest. And the lander, even if they are launched on the same launch vehicle

We would put the lander at the high altitude orbit to protect it from radiation, wait until the orbiter maps the surface, then we will zoom in and come down. Nothing will replace in situ measurement. There will be always uncertainty until you actually grab some of that ice and measure it in a mass spectrometer. The additional thing we need to be thinking about is we need to learn how to land on Europa for the ultimate mission where actually we will have to drill. So this lander that we are talking about will have a great scientific value, but also it will have the value of learning

how to land. That is what we did on Mars. First we landed Pathfinder, then we drove a little bit, then Opportunity, and then Curiosity. So I think we have enough information that we do not have to wait for a mission to be completed before you get to the next mission. We have worked a strategy that you can do it on a much faster time.

Dr. LUNINE. Yes. And then just very briefly, Congressman Honda, there is a very important distinction that has to be made between habitability and looking for life itself. And in the case of Europa we are still at the stage of determining whether Europa is habitable. The saltwater ocean indeed seems to be there. But what we still do not know yet is whether there are organic molecules. In Europa it is possible that there were never any, or they have all been essentially exsolved into space in some way. So that is crucial. And then the whole issue of whether there are hydrothermal systems at the base of the ocean to generate the gradients in energy that life would need, we need the clues again from the minerals that might be coming out of plumes that might be deposited on the surface. So the mission as it is constructed today will really address the habitability of Europa. And if those indicators are positive then going after the question of whether life actually exists there becomes the primary goal at that point.

Mr. CULBERSON. Thank you. Mr. Jolly.

Mr. JOLLY. I see they rang for votes. I will be very brief. I know this is a priority of the chairman so I want you to have as much time as possible. The chairman has been very helpful to me in the Gulf of Mexico and making sure we know how to count fish, so I am happy to support your initiatives here in space. My only question is in these oceans you are finding are there any red snapper in them?

But look, we have the right chairman, the right ranking member on these issues on right now. I am excited to support what you are doing. So thank you all for being here today. I appreciate it.

Mr. CULBERSON. Mr. Fattah.

Mr. FATTAH. Thank you. It is always with mixed emotions, your retirement is both well deserved but your leadership has been extraordinary. I visited the Jet Propulsion Laboratory. I was on the floor with you when the Mars Rover landed on the surface and it was an extraordinary success for the Jet Propulsion Laboratory and for NASA, for our country, and for science worldwide. So I want to congratulate you on all your hard work and your success at the laboratory, and wish you well on your next endeavor. I am sure there is a second act or a third act here.

But I wanted to ask you a couple of questions. Given the fact that you are stepping off the stage, if you could give the committee some reflection on, you know, we at one point had a lot of back and forth. It was pretty lonely in advocating for commercial crew and commercial cargo in the space technology portion of the NASA budget. Because there was a lot of buy into what we might call the old NASA, right? And so there was this big tug of war that has now been settled and we have a robust, competitive, I think, commercial crew operation. So let us just talk about, so it really puts NASA and the Jet Propulsion Laboratory in the position to focus in on exploration. So if you could give us a few minutes on your

thoughts about where we are in terms of the decision package around these issues that would be helpful.

Dr. ELACHI. OK. Sure, I would be glad to do that. Let me first start by saying I am retiring from being the JPL Director but I will be Professor at Cal Tech, which I am presently. So I will stay engaged. I mean, I spent 40 years on this amazing quest of exploration. So I will continue to be engaged in that one.

Now on your second one, I think it is like every time NASA develops a capability we need to turn it over to the commercial sector so they can make a business out of it. That has happened on telecom satellites, GPS. And NASA to be exploring the next frontier. That is what our agency should be doing and I think that is what our agency is focusing on doing. So I think the commercial sector, particularly in the launch area, should be able to support that activity so we can spend our effort either on a more capable launch vehicle, like the SLS, or an exploring mission, like Europa.

Now talking a little bit on technology, I want to add one statement. When we landed Curiosity, of course I was proud of the landing of Curiosity, and we were delighted that you and your daughter——

Mr. FATTAH. Yes.

Dr. ELACHI [continuing]. Were there. But what I was particularly proud of is all over it was written Made in the U.S.A. Because almost every piece of it, we do not import this stuff. We actually build it in the United States. So ever dollar we spend in our space program is spent in the United States for jobs, for developing technology, and so on. And the critical element was investment in technology and enhancing our capability to do these amazing things. These things do not happen. And no commercial sector will invest in technology which is needed 10, 15 years from now. And that is what NASA should be doing. So I am a strong advocate of the technology program for NASA. Because that is what enables the future for us. And at the same time, to turn over the things that the commercial sector can do to the commercial sector to do that. And I think that is the NASA strategy that is being advocated today.

Mr. FATTAH. Well, thank you. And I want to thank the chairman for his extraordinary leadership, not just in terms of Europa. Because he has been I think a robust supporter of our space effort. And we again are thankful that in the omnibus that we were able to get a very good number on commercial crew and space technology, technology, technology, technology. And I brought my daughter out there because we wanted to, she is interested in Cal Tech. So she is 17. She is honor roll, 99 percentile. It is only between the University of Texas and Cal Tech. You know, who knows? Thank you. Thank you.

Mr. CULBERSON. We have got two votes. And Mr. Honda would like to come back. I would like to come back. So if we could recess briefly, we will take these votes and then we will come back and have a few more questions. So the committee will stand in recess briefly. Thank you.

[Recess.]

Mr. CULBERSON. All right. Thank you, Mr. Honda.

The hearing will come back to order. We have finished up our votes and I appreciate very much your patience with us taking a brief recess while we finished up on the House floor.

I wonder if I could to ask Dr. Elachi in particular. Of course, as you know, the fiscal year 2016 Appropriations Act directed NASA to launch a mission to Europa with a lander in order to confirm the presence of organics. If I could ask both of you, first of all, how essential is that we land on the surface in order to confirm the presence of organics?

Dr. ELACHI. I think in order to make sure we have confirmation, you really need to make direct measurements and use it in a mass spectrometer to do that.

Mr. CULBERSON. On the surface?

Dr. ELACHI. On the surface. We don't do that if there are plumes. So the only way to make sure we do that is to land on the surface and make direct measurement, take samples and make direct measurement, because any other way you are going to be still uncertain. So that is a direct, important thing.

The other part I want to emphasize is also you need to learn how to land on the surface of Europa for the longer term and if this was in our capability to do that. So clearly a lander on the surface, in my mind, is a necessity in understanding the oceans on Europa.

Mr. CULBERSON. Dr. Lunine.

Dr. LUNINE. So I have participated in some of the discussions on the lander payload and it is a very carefully selected payload that is designed to give us the essential information we really need to go the next step to look for life, if in fact everything turns out to be positive.

And so one of the things that is essential about the lander is the ability to sample deposits that are on the surface that may be partially covered up that may not in fact be exposed to the orbiter remote sensing. And so we want to have the opportunity to use both the fly-by spacecraft and the lander together to select the right landing site, to put the lander there and then to sample the materials in situ.

And we may get lucky with that in situ analysis. I mean, we may actually find evidence that the organic molecules are being modified in some way by biological processes.

Mr. CULBERSON. So you would agree, the only way to be certain is to land on the surface and actually test the ice deposits on the surface, that is the only way to be sure?

Dr. LUNINE. That is the only way to be sure, but it has got to be done in concert with that fly-by spacecraft——

Mr. CULBERSON. Of course.

Dr. LUNINE [continuing]. Because we need to understand what the nature of the surface is at a level of resolution good enough that a lander can be put in the right place.

Dr. ELACHI. Actually, if you would let me add one thing. When you look at the Decadal and what are the science that they listed, we did generate a table which looked at what can the orbiter do. And the orbiter can do the majority of the science, but it cannot answer directly the question of the organic on the surface. So that was a gap that the orbiter could not do and that is why the lander is critical for this mission.

Mr. CULBERSON. And that is why, of course, as our bill states, the goal of this mission is to achieve the scientific objectives of the Decadal Survey, which as you have just confirmed for the record has to include a lander if we are going to answer that essential and most exciting question of all, is there life on other worlds.

And if I could, Dr. Elachi, ask about when does NASA intend to solicit instruments for the landers with an announcement of opportunity in fiscal year 2016?

Dr. ELACHI. OK. Basically, I mean, again, that is a question NASA would need to answer, but NASA deserves credit, they just sent an email to the broad science community inviting people to submit that they would like to work on this science definition team. And they stated in that letter that this is for about three months where they would work with JPL, with NASA on defining the payload. So they should be able to get that work done, I would say, by early summer time frame. And then NASA will have to go through its process.

So that is something that you need to address with NASA of when will they issue that announcement of opportunity for the instrument. In my mind, the earlier is the better because the payload is the key driver for developing the lander, because we can do a certain amount of work, but until we know what instrument you need, how much samples you need to get, what volume you need, it is hard to do the detail design. So it is critical that the AO and the selection of the payload, is done in the most expeditious way.

Mr. CULBERSON. Well, we will push NASA to make sure they get this done as rapidly as possible. And I also hope that we will see at least two ways to verify the organics with the mass spectrometer and the Raman on the same lander. Because if we are going to go all this way and make this exciting mission, make sure that we actually are detecting organics, it makes sense to double check it, doesn't it?

Dr. ELACHI. Yes, I agree with you. And the design, the very preliminary design that we present to NASA will accommodate at least two in situ instruments, will accommodate motion monitor to look at any vibration and will accommodate imaging.

Now, if NASA decide and the science group decide that they need more instruments, we can do that, but that makes a lander more and more complex. So that is a trade which have to be done with the science community of what is an optimum payload which enables us to answer the question, but also can be done with a reasonable risk.

Mr. CULBERSON. And the payload will be comparable to that which landed on Spirit and Opportunity on Mars in terms of the weight and size?

Dr. ELACHI. I don't know about the weight and size, but at least one of the instruments, the Raman spectrometer, would be based on heritage from Spirit—not Spirit, unfortunately, but from Curiosity, we have a Raman spectrometer planned for Mars 2020, but I will let John tell you.

Mr. CULBERSON. Yes.

Dr. LUNINE. Well, and I just wanted to add that you mentioned having a mass spectrometer and Raman allows you to have backup and have two ways of detecting the organics, the Raman also gives

you some information on structure that is important that you may not get from the mass spectrometer, and understanding aspects of the structure of the organics in telling how fresh they are and where they come from. Were they part of a biological process of some kind or were they not?

Mr. CULBERSON. Yes.

Dr. ELACHI. That combination will be very powerful.

Mr. CULBERSON. I will have a couple followups. I want to recognize my good friend, Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman.

Through these discussions, I am sort of developing a picture in my mind that one of the things we want to do is to be able to understand through various techniques the possibility of life, whether it is through indirect or direct techniques. And also and prior to landing on the surface, it seems to me that we need to know how firm or what the structure is, so that it will sustain a landing. And then also, you know, inserting ourselves on a planet, I am a little concerned about contamination too.

So could you talk a little bit about the kinds of testing that needs to be done? And I know that you talked about handedness, that seems to be important, the issue of having ability through the indirect detection of what processes that you want to go through in order to see what is down there. And the types of techniques, I think I heard fly-through, plumes, things like that. Are these all necessary processes in order to determine whether the surfaces can enable a landing of a craft on the surface of the planet?

Dr. LUNINE. Well, let me talk about the life test and then I will ask Dr. Elachi to talk about the questions of certifying the surface for a safe landing, which is really a different subject.

So I think that the fly-by spacecraft will be able to pretty quickly tell us the coarse essentials about habitability. You know, does it see that there are deposits of organics on the surface. It is not going to be able to tell us in detail what the organics are, but it will tell us whether there are carbon-bearing molecules near the fractures, for example, which we don't know and Galileo was not able to tell us.

Galileo was able to tell us that the ocean is there and salty. There are indications of salt deposits on the surface, but again Galileo couldn't tell us which kinds of salts. So we really for Europa have this rudimentary information that I think the fly-by spacecraft will very quickly develop into a full profile of how habitable Europa really is.

And then of course the next step, both from the fly-by spacecraft and from a lander, is to determine whether there is biological activity. There are a number of ways to do that. Of course direct detection of organisms requires potentially very elaborate instrumentation. It is better to analyze if there are fresh organics on the surface to look for evidence of a preponderance of left-handed or a deficit of right-handed, or vice versa, organic molecules, if there are amino acids. And in general——

Mr. HONDA. And could you explain——

Dr. LUNINE. Yes?

Mr. HONDA. Could you explain the difference and the importance of?

Dr. LUNINE. Yes. So life of course life on earth, it is all biochemically the same, we have no other example of life. And the amino acids that life uses, with only small exceptions, all have a particular orientation or handedness, the way that the carbon atoms are attached to the molecules themselves, and that actually allows the amino acids when they are arrayed in the chain to make a protein, to actually allow that chain to fold properly to make the protein. If you had a mixture of the left-handed and the mirror form, if you had a random assortment, when they are arrayed on a chain, you don't get a protein.

Now, it doesn't matter if it is left-handed or right- handed. It could be all right-handed or it could be all left-handed, but it has got to be one or the other. And so identifying, first of all, if there are amino acids and, secondly, are they all left or all right, is one very powerful example of a life test, a test for life.

Mr. CULBERSON. Chirality?

Dr. LUNINE. That's chirality, exactly.

Do you want to talk about the surface?

Dr. ELACHI. Yes. I think on the question of the safety of landing on the surface, as I mentioned earlier, the orbiter is going to be taking very high resolution imaging of the surface. Now, remember, Europa is the size of our moon, so it is a big satellite. So we will be taking the images to decide what areas are scientifically valuable and safe to land.

In addition to that, as the lander is coming down, it will have the capability of actually taking pictures as it is coming down and move to make sure it is in a safe place. That technique we are going to be demonstrating on Mars 2020, so we will have it well understood.

And the third thing on top of that, the way we land, we are putting the lander inside the pyramid similar to what we did with Spirit opportunity and Pathfinder. So even if it lands on the side or if there is a rock next to it, it can unfurl and right itself up.

So these are three steps which will assure us that we will be able to land safely on the surface.

Mr. HONDA. To the chair. The reason I asked about having this contamination connected to landing or fly-by or fly-through, whatever the term is, I was trying to figure out if he can determine the amino acid handedness through a fly-through, so that you have that information prior to landing. I mean, are there ways that you can do that?

Dr. LUNINE. Well, the only way to do that would be if Europa had a plume. If it has got a plume of material where you have fresh material pouring out of the ocean that can be sampled by instruments, potentially it could do that. However, the Europa fly-by spacecraft doesn't actually have a device for measuring chirality, and that is actually a fairly complex type of instrument.

Mr. HONDA. I'm sorry, measure what?

Dr. LUNINE. To measure the left—excuse me, sorry—to measure left versus right-handed, that is not part of the payload. It can detect molecules, but it can't tell you what the structure is in terms of left or right-handed. And that is a type of instrument that requires some development, probably should be on a lander.

Mr. CULBERSON. Thank you. You would have to make that measurement on the surface on the spot in order to be able to determine the left or right-handedness?

Dr. LUNINE. In fresh material that has not been damaged by the radiation field.

Mr. CULBERSON. Right. And, I also understand from the briefings that I have been given that the speed of fly-by is so high that any organic material that might be in that plume would be disintegrated by it. So another reason to land on the surface is the organics in that plume when you fly through it would probably disintegrate, as I recall this morning——

Mr. HONDA. Well, Mr. Chairman, not having that experience of hearing, is that plume created naturally or is that induced through, you know, creating the plume ourselves?

Mr. CULBERSON. No, the plume is created naturally. It is like Enceladus, the ocean is venting through cracks in the ice into the lower pressure, because it is essentially a vacuum. And we have seen it in Enceladus, detected a plume on Europa once or twice from Hubble.

Dr. ELACHI. Let me mention one thing. First, on Enceladus we see the plumes coming regularly. So there you have confidence and Jonathan has been thinking of how do you measure that. On Europa we have not confirmed that there are plumes.

Now, you could think, well, I could impact the surface and create the plume, but when you impact the surface you have to do it at extremely high speed and that could create a lot of damage for whatever is on the surface. I mean, damaging the molecule you are trying to measure, because it is like a bullet to do that.

So I am not sure that is a good or wise technique to do that and we don't know if naturally there are plumes. So clearly the best approach and the safest approach is to put a lander, a soft lander on the surface, and drill below the surface and make that measurement.

Mr. CULBERSON. And the pyramid you are discussing, it would land similar to Spirit and Opportunity, there would be airbags around the pyramid?

Dr. ELACHI. I am not sure we will put the airbags, but it would be very similar, the shape would be very similar, and we are in the early stage of looking at the techniques. By bringing it with a sky crane and being able to have control of where we land, that addresses significantly the risk.

Mr. CULBERSON. Could you talk a little bit about what we know about the ice? The surface is, it is a free-floating ice shell, not sure how thick, but the age.

Dr. LUNINE. This is a very interesting question. It is a very young surface, there is only one really old, large crater on one part of Europa. And there are places on the surface where the crust may be as thin as a few hundred meters perhaps, places where you see these cycloidal ridges that appear to be a response to the tidal pull, the tidal stresses as Europa goes around Jupiter, those are the places where the crust may be very thin. There are other places, for example where this one crater Pwyll is located where the crust appears to be thick, it may be 10 or 20 kilometers thick.

So you have to imagine that, as you said, Mr. Chairman, this free-floating ice shell just has a variation in thickness as you go around Europa. And one of the important goals of this mission is to determine, you know, the ice thickness in various places and determine where the ocean is really closest to the surface.

Mr. CULBERSON. And if the surface is that young, it obviously implies that it is being continually replenished and that that ice is diving down into the ocean and coming back up. And because of the intense radiation, I think I have read that the hydrogen atoms are being stripped away from the H_2O, which means it is oxygen-enriched ice going down into the ocean and releasing that oxygen, so it is plausible that that ocean has been oxygenated for billions of years?

Dr. LUNINE. Yes, this is a very interesting aspect of Europa that this may in fact be a primary source of energy for life are these oxygen atoms that have, as you said, the hydrogen has been stripped and then these very oxidized species, peroxides and so on, are being introduced into the ocean. By one estimate and one paper I read, there may be as much energy from that as we have in certain oxygen-rich aerobic systems in the Earth's oceans.

Now, you wouldn't want to try to form life in that environment, right? Because oxygen is a destroyer of organic compounds. So we would also like to know whether there are places in the deep ocean of Europa which are not exposed to quite that much oxygen or at least were not in the past, because in order to actually build these organic molecules before life itself began, you would have had to have had a relatively oxygen-free environment.

Mr. CULBERSON. I also understand from talking to Dr. Robert Ballard that these mid-ocean ridges, which are not visible here, the largest volcanic system on the Earth, the 40,000-mile long mid-ocean ridge, that Dr. Ballard told us that for years geologists couldn't figure out the chemistry of the Earth's ocean, they didn't understand why it had the mixture of chemicals that it did, that the rivers flowing into the ocean, you couldn't account for the chemistry of the ocean just based on rivers until they discovered these mid-ocean ridges. And Dr. Ballard points out that the entire volume of Earth's oceans circulate through those mid-ocean ridges every few million years, he thinks maybe 4 to 6 million years, and that injects a tremendous amount of chemicals into the earth's oceans, which account, once they did that calculation, it matched perfectly and it explained why the Earth's oceans have the level of salt and other chemical elements within it.

And clearly wouldn't you say that is a reasonable analogy to what we see in Europa where the silicate, you are detecting silica in the plumes on Enceladus, almost certainly, you have got a rocky bottom to the oceans of Europa, so is it reasonable to assume that you have got similar circulation of the salt water on Europa going through those volcanic black smokers, we will probably have black smokers on the bottom of the oceans of Europa as we see on earth?

Dr. LUNINE. Yes, that is a very interesting question for Europa. And the fact that it is a large body that has a large rock core makes it likely that there is some sort of hydrothermal circulation of water through the hot rock. Now, whether it is a black smoker or some of these other types of what are called off-axis hydro-

thermal systems that are a little bit cooler is not really clear. And one of the goals of this mission, by determining what are the kinds of salts that have been deposited from the interior and what other kinds of mineral evidence might there be on the surface, we might be able to know what type of hydrothermal system is present.

On Enceladus, what is interesting is that the Cassini data from the mass spectrometers are good enough that the pH, the acidity of the ocean has been estimated from those data, and as well the temperature in a very sort of crude way, from these silica particles that have been sampled by Cassini. And those data suggest that there is a hydrothermal system at the base of the Enceladus ocean, and it is more like the low-temperature hydrothermal systems on Earth that are off the mid-ocean ridge, off of the axis. There is one called Lost City, for example, and it has a temperature of about 50 Celsius and it has a high pH, as Enceladus does. It has a different kind of chemistry and that is what looks like might be happening at the base of the Enceladus ocean.

So it will be very intriguing to see what is happening in the Europa ocean, whether it is similar to that or more similar to the higher temperature black smokers.

Mr. CULBERSON. Mr. Honda.

Mr. HONDA. OK. Leaving the planet and coming back to earth, in your independent opinion, what is the estimated life-cycle cost of the Europa orbiter mission both with or without a proposed lander? And how soon do you believe a Europa orbiter mission could be launched and what assumptions must be made to support that launch date? And how long would inclusion of a lander delay arrival of a spacecraft to Europa? I think you alluded to that, including development time and transit time.

Dr. ELACHI. Let me answer it first on the technical side. On the technical side, the two are complementary, it won't impact. We can move ahead with the orbiter on its present schedule. At the end, the key driver is going to be the funding for it. And that is what we are developing now to provide NASA for the funding profile that is needed based on the direction which came from your committee about when to do the launch. So we would be providing that to NASA.

Now, originally, maybe your concern comes, originally we were thinking of having the lander attached to the orbiter and, therefore, the orbiter will have to wait for the lander to be finished. That is not our plan now. We found that technically that is not a good approach. So we will have the orbiter and the lander as two separate spacecraft. And as I mentioned earlier, three years from now we can decide do we launch them together or do we launch them separately.

Now, for Jupiter, fortunately, we can go to Jupiter roughly every year, about every 13 months. So you can plan it depending on the readiness of the orbiter, the readiness of the lander, the availability of the launch vehicle, but you have a shot every year to actually do that, if we decide to do them separate.

And so we are doing all these assessments, should they be launched together or should we launch separate, but they will be developed separately, so it won't impact the orbiter's schedule.

Mr. HONDA. And development time and transit time, it is dependent on what our decisions are then?

Dr. ELACHI. The time of development is, once you select a payload, you need roughly about 6 to 7 years to be at the launch pad. That is from our experience on Mars 2020, Cassini, Galileo, all these missions. And if you try to do it much shorter, that is not wise, because you are taking big risks. If you wait longer then that it is not efficient, because you have built your team and all the activity, if you start stretching it, that is not the way to do things.

So really the driver is, the trigger point is, in my mind, the selection of the payload, and then you can add 6 to 7 years, assuming funding are available, 6 to 7 years to be ready to be on the launch pad.

Mr. HONDA. I mean, the Chairman will be here more than 6 or 7 years, right?

Thank you, Mr. Chairman.

Mr. CULBERSON. Just to wrap up on Europa, I want to make sure I understand that you have got an oxygenated ocean, this obvious evidence of a lot of heat, probably circulation through those volcanic ridges, and the ice would also protect that ocean from asteroid impact and radiation, so a very stable and secure environment for potentially life to not only begin, but to then be sheltered for essentially the life of the moon; is that accurate?

Dr. LUNINE. As far as everything we know today, yes, that is right. And what we don't know today is how much carbon and nitrogen-bearing material is in Europa and we really need to know that.

And if I may, Mr. Chairman, the first proposal that I wrote for an instrument on a Europa mission was in 1999. And so some of us have been waiting 17 years for a mission to get going, and that was of course just two years after Galileo discovered evidence for the ocean through its magnetometer. So, you know, I have to say that it is past time to get to Europa, and the sooner that we can get there to explore this incredibly fascinating moon that may well hold life, the better.

Dr. ELACHI. Let me add to what Jonathan said. So that reflects that the science community have been thinking, so it is well thought of what needs to be measured. And that is why the Decadal indicated measurements which as of now can only be done with a lander.

The other question on the radiation, I am not an expert, but I ask people at JPL, all that you have to do is to go just a few centimeters below the ice and you are somewhat safe from radiation. That is why Jonathan emphasized that when we take the samples, we need to drill a few centimeters, a few tens of centimeters, so you get fresh ice coming from it which is not bombarded by the radiation. So you don't have to drill too far to actually find what we are looking for.

Mr. CULBERSON. And I want to stress too, of course, for the record that this is obviously a keen interest of the committee, of mine, but it is the top priority of the Decadal Survey. This is something that we are pursuing, Mr. Honda, and the subcommittee is supporting, because this is the consensus of the scientific community in the Decadal Survey, correct, that we need to go to Europa?

Dr. LUNINE. Yes, that is correct, absolutely.

Dr. ELACHI. Yes, correct.

Mr. CULBERSON. And I want to also, if I could, because the other purpose of this hearing today and we will wrap up here in a few minutes, but I want to lay the foundation for the future. The idea of this hearing was to talk about the exploration of these ocean worlds as a great opportunity to discover life perhaps in our own backyard.

Talk to us about, if you could, as you mentioned, the oceans of Enceladus, that is a free-floating ice shell as well?

Dr. LUNINE. Yes, yes, it is a free-floating ice shell. It is thicker, it is about 30 kilometers thick, as far as we can tell. So we really are depending on the plume, sampling material coming out through the fractures into space in order to learn more about that ocean's habitability and the possibility that life is present.

Mr. CULBERSON. And the water—go ahead. Sorry, Dr. Elachi.

Dr. ELACHI. No, I just want to mention, you probably know it, but to the credit of NASA they added Enceladus and Titan to the potential targets for the New Frontier program. This it is to look at an ocean program which involved Flagship mission, New Frontier and Discovery. So NASA did add Titan and Enceladus as potential candidates for the New Frontier mission. And Discovery is a little bit harder, because the outer solar system is pretty far away to do that.

Mr. CULBERSON. Right. And those of course would also be prime candidates for launch on the SLS? They are smaller spacecraft, but again to get there rapidly, you would need the SLS?

Dr. ELACHI. Again, I mean, the biggest benefit of the SLS is the speed and that it can carry more mass. We are in the process of thinking of ideas for the Titan mission and the Enceladus, and Jonathan is a key player in both of them. Depending on what the scientists come up with, that will lead to what is the right launch vehicle.

Mr. CULBERSON. How deep is the ocean on Titan, do you think, or is it a sea?

Dr. LUNINE. Well, there is a liquid water ocean on Titan and in fact the Cassini evidence is that it is also a decoupled shell, but it is very deep. It is at least 60 kilometers and it may be more like a hundred kilometers below the surface.

So of all three of those bodies, sampling material from the Titan subsurface water ocean is going to be the most difficult target. But there are also these hydrocarbon seas on the surface and they may be an interesting target, and they are exposed to the atmosphere, you can land on those.

Dr. ELACHI. To answer your question, from the Cassini mission we know those surface oceans, which are made of hydrocarbon, are the size of the Great Lakes. So this is not like a pond, but it is not a Pacific Ocean. But they are very large lakes. And as Jonathan mentioned, the amount of hydrocarbon which is in them exceed by how much for——

Dr. LUNINE. Two orders of magnitude.

Dr. ELACHI [continuing]. Two orders of magnitude how much hydrocarbon there is. So that could be an indicator of some exotic life, a different way of life.

Mr. CULBERSON. Mr. Honda, dive in any time.

Mr. HONDA. So I guess I will close with this question then. With that discussion then, it sounds like there is that possibility or have you thought about how we recycle the assets that we are already developing or we will be using, would that be recyclable and be able to continue to use as we seek out other solar oceans?

And I guess the other would be, should we be looking at building smaller fleets of assets, so that as we are pursuing this project we could be thinking about in a parallel way building smaller fleets to continue this search for ocean worlds that are out there?

Dr. ELACHI. I think what you said is the wisdom of having a program. You need to think of all different elements to explore Europa, Enceladus Titan, in similar ways that the Mars program have been thinking about. And it could be a combination of large spacecraft, small spacecraft, boats, balloons. So the benefit of having a program is that you can do this kind of thinking that you are mentioning.

And also it will allow us to build on, one mission building on the prior mission, both from science, but also from hardware as you develop things. So it is the same thing on Mars we built up from Pathfinder to Spirit to Opportunity, then to Curiosity, then to Mars 2020. And now we are looking at technology such as little helicopters which can augment those measurements. And that is enabled because we are thinking as a program, not one mission at a time and then wait until we get the results from it.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. CULBERSON. If I could also to follow up, because I want to talk a little bit about it before we wrap up, the purpose of this hearing today is to talk about the next step and it is developing a program like we had with the Mars mission. We have discovered these oceans that exist in the outer solar system, they are undoubtedly, probably very common throughout the universe, and it is important that if we are going to discover life, it is going to be in those oceans.

Talk first for a moment about, for example, what other moons in the outer solar system do you think could have oceans of water?

Dr. LUNINE. Well, we have some evidence for an ocean in Callisto, which is one of the other Galilean moons of Jupiter. It might be a very thin ocean. It is somewhat mysterious that it would have one, because it seems to be rather cold and dead, but the evidence seems to be there.

Triton, which is a moon of Neptune, is very intriguing because it's a large satellite, it was probably captured from the kuiper belt, it is the size of Pluto, and it has some activity on its surface. When Voyager 2 flew by in 1989, it found that there were these plumes of material coming up that deposit dark streaks across the surface. And while there are some models that say that this is just driven by solar heating of the surface, the fact that we don't see this on Pluto in the same way suggests that maybe this is actually internal activity that is being expressed at the surface.

So Triton is another object that might have an ocean. It is a long way away. I mean, Neptune is at the edge of the solar system.

Mr. CULBERSON. Any of the moons of Uranus indicate any evidence of——

Dr. LUNINE. We don't know, because, you know, Uranus is tipped on its side. And so when Voyager 2 flew by Uranus, it was essentially a bull's eye where the whole satellite orbits were face-on. And the whole fly-by was quick, it was basically through the target and the spacecraft had to look very quickly and take a few pictures of each moon. We just don't know very much at all about those moons and going back at some point and understanding more about them is very interesting. They are large, four of them are large, they might have oceans, but we just don't have any evidence.

Mr. CULBERSON. So the ocean moon exploration program that we have outlined in our bill will be obviously focused initially, the first mission to Europa, Enceladus and Titan would be the most immediate and obvious targets.

And what we learned from the New Horizons mission to Pluto, large amounts of water in evidence there on Pluto too, isn't it? Frozen obviously, but you found water on Pluto and that was unexpected.

Dr. LUNINE. So, well, Pluto, just based on its density, was thought to be an ice-rock world. What is surprising about it is that there is a lot of geology, that the ice itself seems to have been modified by geologic processes. And there are deposits on the surface of other ices, nitrogen ice, carbon monoxide, methane, which themselves have been flowing across the surface. So it is a very complicated world. The way it looks geologically suggests that maybe in fact there is activity inside Pluto that has heated it and melted the water ice. Now, whether that is still going on today, we don't know.

But every place we go in the outer solar system is a surprise. There is much more activity, there is much more dynamism, if you will, in these bodies than I think any of us would have predicted.

Mr. CULBERSON. The point I wanted to drive at is that everywhere we look too out there, there is a lot of water.

Dr. LUNINE. Absolutely, yes, there is a huge amount of water in the outer solar system.

Mr. HONDA. There has been some question about Earth science——

[Audio malfunction in hearing room.]

Dr. ELACHI. Clearly, I think as we develop an Ocean Worlds program, we should be looking at what can we do also in our oceans. And that is why Dr. Ballard has been involved in some of these activities, because we can learn both ways. By exploring our ocean, we can learn about oceans outside our planet and vice versa.

I have been around in this business for 40 years and I found many times as we develop things for planetary exploration, the technology and the technique and the knowledge are directly applicable back to our own planet. I started the JPL to work on the Magellan mission which had an imaging radar on it. Guess what? Now, imaging radars are being put in orbit around earth based on some of that technology that we developed for Magellan.

And I have no doubt, whatever we do on Europa and the technology for submarines or drilling, will have some cross-benefit with our own ocean and vice versa, because here we have to develop robotic, small submarines which are capable of making some very advanced measurement. I could see people interested in having

dozens of those being put in our own ocean to study what is below the ice in the Arctic and Antarctic.

Mr. CULBERSON. Thank you. If I could, having the benefit of your presence here, Dr. Elachi and Dr. Lunine, talk about the far future, because one of the exciting things about this Ocean Worlds Exploration Program is it will be laying the foundation to develop the next generation of rocket propulsion and to take NASA on to the next level, because when we do discover life in another world, I think that will encourage the public to support the level of funding NASA is going to need.

Let me ask first quickly about the work that NASA is doing with the Department of Energy to support radio isotope power systems, is the level of funding that we have in this year's bill sufficient, and are you satisfied with the work that is being done to increase the power output and to reduce the mass and size?

Dr. ELACHI. To the best of my knowledge, from what I have been told, I think it is appropriate and an appropriate level, but again that is a question that headquarters probably can answer. But for our purpose, looking at the near-term mission that we are discussing, I think what is available now and the new production that DOE is doing are satisfactory for that.

Now, in the longer term when we start talking about a lander to melt our way down below the surface, then that is why I said it is important to put some work on the technology of what is needed, so we can assess exactly how would you do it and will we have enough radioactive material to do that.

Mr. CULBERSON. That would be the second mission to Europa would be to get through the ice, this mission will involve some artificial intelligence because of the distances involved. The computers on board will have to make a lot of decisions on their own as they are approaching the surface; is that correct?

Dr. ELACHI. Absolutely. It has to be all done autonomously, because it takes a couple of hours for the signal to go up and down. So everything has to be done autonomously and that would require the advances that you are talking about.

Mr. CULBERSON. And that second mission would require a heat source sufficient for a submersible vehicle to melt through the ice, drop out into that ocean, and then transmit images and information back to the surface to tell us what is beneath that ice and we hope reach the bottom of that ocean.

Dr. ELACHI. Yes, that is correct. I mean, I don't know, but depending how thick the ocean is.

Mr. CULBERSON. The ice, rather, yes.

Dr. ELACHI. But for that mission you clearly need nuclear capability, because it is going to require a long time. So the lander that we are doing, that we are talking about now, the precursor lander, that doesn't require a long time. It is required to capture samples, make measurements. And the fact that it is static, it is not a rover, most of the science can be done in a couple weeks, therefore nuclear material is not needed for the lifetime, it can be run with batteries. But as we head toward drilling down, then I don't see any option other than having nuclear to get enough power to be able to do that, or energy to be able to do that.

Mr. CULBERSON. Let me wrap up with, talk about WFIRST and looking out beyond our solar system to identify earth-like planets around nearby stars and the chronograph that you are developing in the Starshade, because it is extraordinarily exciting and looking out into the future, the WFIRST is essentially a flagship mission in terms of investment, that would be second, then we do the Europa mission, and then the next big mission would probably be WFIRST.

Could you tell Mr. Honda and I a little bit about the WFIRST mission and its importance, coupled with Starshade, in identifying and then spectrally analyzing the atmosphere of earth-like planets around a nearby star?

Dr. ELACHI. OK, let me mention on the techniques and then Jonathan can add on the science.

WFIRST just passed its Phase A, so NASA is proceeding through the process of doing that. The baseline mission, which was a top priority with the astrophysics community, that baseline mission focuses on two topics, dark energy, dark matter, and on exoplanets. The mission now, the baseline, include the chronograph inside the spacecraft itself. That allow us to make certain measurement of detecting planet directly by blocking the light from the star and be able to see the planet, and it will detect planets of certain size and distance.

We are working on technology, let me emphasize, it is technology now, for a potential Starshade which will augment the measurements which are being done by the chronograph. But that technology, we need a couple of years to demonstrate fully that technology and bring it to a level that detects Earth-size objects. The Decadal can then assess the scientific value versus the risk.

So we are moving ahead on the technology, but as of now the baseline WFIRST mission only include the chronograph inside the spacecraft.

Jonathan.

Dr. LUNINE. Well, yes, I would only add that of course the opportunity to be able to determine the composition of the atmospheres of Earth-size planets around other stars is the ultimate goal. And in a way this has already started, because with Hubble and with Spitzer it has been possible to determine the atmospheric composition of large planets, giant planets, using the transit technique. And the James Webb Space Telescope will extend that down to super-earths, objects that are two or maybe three times the size of our own Earth. That will tell us a lot already about whether these super earths are like our own Earth in terms of atmospheric composition or perhaps are more like Uranus and Neptune, small versions of those planets.

I mean, clearly beyond that, if we want to be able to determine whether there really are habitable earths the size of our own planet, we will have to take the next step and that would have to be done beyond JWST, maybe with WFIRST, maybe with something else.

Mr. CULBERSON. But you would be able to with WFIRST, the chronograph that you already are developing, to be able to directly image or be able to pick up the light of these exoplanets and spectrographically analyze their atmospheres, they could detect—and

please for the record, I just want to confirm, the smoking gun for life would be methane, oxygen together?

Dr. LUNINE. Well, yes, that would be the smoking gun. But because I am not involved in WFIRST, I should ask Dr. Elachi to describe the capability.

Mr. CULBERSON. Could WFIRST do that for us, Dr. Elachi, to determine——

Dr. ELACHI. My understanding and, again, you might want to do a hearing on WFIRST, because I am not fully up to speed,—my understanding is the chronograph will allow you to image separate the light coming from the planet, mostly for planets larger than Earth, but it was the chronograph. The Starshade will bring you closer to Earth-size planets. How accurate the spectroscopy can be done, that is something that I really can't answer, that is not my expertise, and I think there are people who can answer specifically that question.

But the key point I think you are making is we will be able to separate the light of the planet from the light of the star by using the chronograph and, as I said, the Starshade will make it even closer to looking at Earth-size planets.

Mr. CULBERSON. We are about to wrap up, but I want to make sure, I have this great opportunity, these two brilliant scientists here with us today and with Dr. Elachi's imminent retirement, I want to make sure I have got a chance to get this on the record, that one of the goals of WFIRST is to not only be able to directly image those exoplanets, but it would have the ability from the briefing that I got at JPL, particularly with Starshade because you don't lose any photons with Starshade, to be able to spectrographically analyze that light from that earth-like planet, it was my understanding from the scientists that briefed me at JPL that they would be able to see the spectrographic signature of methane and oxygen, they would be able to see it.

Dr. ELACHI. I think so. I really cannot tell you 100-percent sure, but, yes, it will be able to do some spectroscopic measurement.

Mr. CULBERSON. And perhaps even industrial pollution, we will be able to see perhaps hydro fluorocarbons.

But nevertheless, that then leads to our kids and grandkids, and I hope one of the legacies that I would like to leave as the subcommittee chairman of this marvelous committee and with your help, Mr. Honda, that not only have we then discovered life in another world, we hope in Europa, identified earth-like planets and picked up the spectrographic signature of an atmosphere that contains methane and oxygen. But I hope also finally, in conclusion, to ask about the development of the next generation of rocket propulsion ion engines that would be able to take a spacecraft to Alpha Centauri, which is about four and a half light years away, and if we could achieve what percent of the speed of light do you think is possible, two percent, four percent, five percent perhaps?

Dr. ELACHI. I don't know, because that requires some new invention, but I was thinking about it as I was sitting here. If I would have told my grandmother, and that is not very long ago that I would be able to hop on a plane and fly to the United States in 12 hours, she would have thought I am crazy. But within a hundred years we have moved from being in carriages to be able to

travel across the country or across the world. So I am sure our children will be smart enough to invent some advanced technology for propulsion to do that.

Now we need to start making some investment. We don't have an answer. I cannot tell you, if you do A, B, C, we will get to one percent or two percent. But, also people think about it for airplanes, it is by investing in the technology, we might get some new inventions that will allow us to go to those kind of speeds.

Mr. CULBERSON. I think Mr. Honda has a question.

Mr. HONDA. What I am getting from the last conversation was analyzing light and light sources is that——

[Audio malfunction in hearing room.]

Mr. HONDA [continuing]. Will tell you the kinds of composition of the atmosphere, because I know that planets do not emit their own light. So I was just trying to understand what we are saying here. Thank you.

Mr. CULBERSON. And then just in conclusion, that is really the final piece of this hearing——

Mr. HONDA. There is no conclusion.

Mr. CULBERSON [continuing]. Was to really, I hope, as a result of the time that I have got, if I have the privilege to stay here as the chairman for that time period, we will have laid the foundation not only to discover life in that other world, but to have identified those earth-like planets around other solar systems, and then develop the rocket technology so that our children and grandchildren will have the opportunity to be witness to the first interstellar missions to Alpha Centauri. It may take 80 years or a hundred years to get there, but perhaps today we have heard for the first time how we here can lay the foundation stones for that to happen.

I want to thank you very, very much for your service to the country——

Dr. ELACHI. Thank you.

Dr. CULBERSON [continuing]. And for the time that you have given us here today. And in particular, Dr. Elachi, thank you for the extraordinary work that you have done for the Jet Propulsion Laboratory, for the nation, for NASA. The incredible discoveries that have been made on your watch I don't think would have been possible but for your leadership. You have woven together the extraordinary talent of the scientists and engineers at JPL, but also have been able to bring together the political support that was so essential to make sure that these magnificent missions were successful. And we will continue to give you all the support that we can at JPL and NASA in general.

And, Dr. Lunine, I want to thank you for being here as well.

Dr. LUNINE. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you very much.

The hearing is adjourned. Thank you.

Chairman John Culberson
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
NASA - Ocean Worlds Hearing
Dr. Charles Elachi

The Jupiter Europa mission was rated as the second highest priority flagship mission for the decade 2013-2022. This decadal survey, *Vision and Voyages for Planetary Science in the Decade 2013-2022* stated in part:

> *If NASA's planetary budget is augmented, then the program will also carry out the first in-depth exploration of Jupiter's icy moon Europa. This moon, with its probable vast subsurface ocean sandwiched between a potentially active silicate interior and a highly dynamic surface ice shell, offers one of the most promising extraterrestrial habitable environments in the solar system and a plausible model for habitable environments outside it. The Jupiter system in which Europa resides hosts an astonishing diversity of phenomena, illuminating fundamental planetary processes. While Voyager and Galileo taught us much about Europa and the Jupiter system, the relatively primitive instrumentation of those missions, and the low volumes of data returned, left many questions unanswered. Major discoveries surely remain to be made. The first step in understanding the potential of the outer solar system as an abode for life is a Europa mission with the goal of confirming the presence of an interior ocean, characterizing the satellite's ice shell, and enabling understanding of its geologic history.*

The Jupiter Europa mission science objective posited in this decadal was to "Explore Europe to investigate its habitability."

1. Please describe how the instruments selected for the Europa clipper mission will respond to this fundamental question: to "Explore Europe to investigate its habitability."

   Each of the nine instruments selected by NASA for the Europa Clipper mission addresses aspects of the mission's overall goal: Explore Europa to investigate its habitability. Key to understanding Europa's habitability is understanding the presence and location of liquid water, documenting the composition and chemistry of surface and subsurface materials, and understanding the nature and locations of chemical energy sources (nutrients). Briefly, here are the primary objectives addressed by each of these instruments:

   - EIS (imaging system) – Map Europa's surface features, especially those which may be currently or recently active, search for plumes, characterize the surface topography, and determine color variations, to understanding Europa's geology and activity level, which are key to understanding the location of liquid water.
   - MISE (infrared spectrometer) – Investigate surface composition, including searching for organics, by measuring the chemical fingerprints of light reflected from the surface.
   - E-THEMIS (thermal imager) – Search for "hot spots" indicative of current activity and potentially of shallow water.
   - Europa-UVS (ultraviolet spectrograph) – Search for and characterize any plumes, which may be direct indicators of subsurface composition, and augment compositional measurements of surface materials.
   - REASON (ice-penetrating radar) – Sound Europa's ice shell with radar waves to search for liquid water within and beneath the ice, and understand how material including chemical nutrients are exchanged between the surface and the ocean.
   - MASPEX (mass spectrometer) – Measure minute constituents in Europa's thin atmosphere and possibly in plumes, to determine the composition of gases and of any organic materials present.

- SUDA (dust analyzer) – Determine the composition of dust particles knocked off of Europa, and potentially in plumes, especially the nature of organics and salts.
- ICEMAG (magnetometers) – Determine the salinity and thickness of Europa's ocean by measuring magnetic fluctuations near Europa.
- PIMS (plasma analyzer) – Determine the nature of charged particles (plasma) around Europa, to understand its composition and to aid magnetic analysis by ICEMAG.

2. Please describe how the science instruments selected for the orbiter/clipper mission will "confirm the presence of an interior ocean, characterize the satellite's ice shell, and enable understanding of its geologic history." (Paraphrase from decadal survey.)

The Europa clipper mission directly addresses the goals for Europa exploration as outlined in the planetary decadal survey, as follows.

Confirm the presence of an interior ocean:
There are three ways that the Europa Clipper will be able to confirm the presence of a subsurface ocean at Europa:

1. The ICEMAG magnetometer, aided by the PIMS plasma instrument, will measure magnetic signals in the vicinity of Europa. Monitoring these signals with each flyby during the mission, scientists will be able to determine if there is a salty ocean that conducts electricity inside Europa, and how deep and salty that ocean is.
2. If Europa's ice is sufficiently thin, signals transmitted by the REASON radar instrument will be able to penetrate all the way through the ice shell, reflect off the ocean's top, and then be detected by the radar's receivers. Analyses of these radar signals can reveal the presence of an interior ocean, even if that ocean is nearly 15 miles below Europa's surface.
3. Engineers and scientists on Earth will be able to monitor the signal from the Europa Clipper's telecommunications system. By analyzing these signals, we can determine how Europa's gravity tugs on the spacecraft as it flies by Europa. Repeating this many times, flying past Europa when the moon is at different positions in its orbit around Jupiter, will

reveal how Europa flexes as it orbits, in turn revealing the presence of a subsurface ocean.

"Characterize the satellite's ice shell":
The Europa Clipper will characterize Europa's ice shell in two main ways:

1. The REASON radar experiment can ping Europa with two different frequencies of radar waves, and the reflected signals will reveal evidence of water and fractures in the shallower and the deeper portions of Europa's ice shell.
2. The E-THEMIS thermal imager will search for and characterize any "hot spots" on Europa, telling of whether and which portions of the ice shell are geologically active and warm today.

"Enable understanding of [Europa's] geological history":
There are several ways in which the Europa Clipper mission will inform us about the geological history of Europa:

1. The EIS camera system will map most of Europa at 100 m/pixel resolution or better, and it will obtain additional imaging at resolutions up to 50 cm/pixel, allowing scientists to infer the geological processes that have shaped Europa over time.
2. Several instruments will work together to determine the composition of Europa's surface across its various geological features, to understand how the geology and composition are interrelated. The relevant compositional instruments are: the MISE infra-red spectrometer, the MASPEX mass spectrometer, the SUDA dust analyzer, and the Europa-UVS ultraviolet spectrograph.
3. By probing through the ice shell, the REASON radar will provide evidence of how the Europa's geology was shaped over time, in in three-dimensions.

The planetary decadal survey continued with the following:

Current State of Knowledge and Important Science Questions

The deep-rooted motives underlying the planetary sciences address issues of profound importance that have been pondered by scientists and non-scientists alike for centuries. Such questions cannot be fully addressed by a single spacecraft mission or series of telescopic observations. It is likely, in fact, that they will not be completely addressed in this decade or the next. To make progress in organizing and outlining the current state of knowledge, the committee translated and codified the basic motivations for planetary science into three broad, crosscutting themes:

• Building new worlds—understanding solar system beginnings

— How did the giant planets and their satellite systems accrete, and is there evidence that they migrated to new orbital positions? Important objects for study: Enceladus, Europa, Io, Ganymede, Jupiter, Saturn, Uranus, Neptune, Kuiper belt objects, Titan, and rings.

• Planetary habitats—searching for the requirements for life

— What were the primordial sources of organic matter, and where does organic synthesis continue today? Important objects for study: comets, asteroids, Trojans, Kuiper belt objects, Enceladus, Europa, Mars, Titan, and uranian satellites.

--Beyond Earth, are there contemporary habitats elsewhere in the solar system with necessary conditions, organic matter, water, energy, and nutrients to sustain life, and do organisms live there now? Important objects for study: Enceladus, Europa, Mars, and Titan.

• Workings of solar systems—revealing planetary processes through time

--How have the myriad chemical and physical processes that shaped the solar system operated, interacted, and evolved over time? Important objects for study: all planetary bodies.

3. Please describe how a Europa clipper and lander mission will address the Current State of Knowledge and Important Science Questions outlined by the decadal committee:

- understanding the solar system beginnings
- searching for the requirements necessary for life, and
- how does the solar system work

The Europa Clipper mission, and a Europa lander, would each address the Current State of Knowledge and Important Science Questions outlined by the decadal committee.

Understanding the solar system beginnings:

Europa Clipper: The MASPEX mass spectrometer will measure the extremely detailed chemistry and weights of gases in the vicinity of Europa, shedding light on the composition of the materials from which Europa formed.
Europa lander: Depending on the instruments chosen, it is possible to make even more detailed and definitive measurements of composition from a mass spectrometer on Europa's surface, further elucidating the original materials from which Europa formed.

Searching for the requirements necessary for life:
Europa Clipper: Searching for the requirements for life (water, elements from which organic materials can be built, and chemical energy/nutrients for life), is the overarching goal of the mission. As discussed above, each of the Europa Clipper instruments addresses objectives that are key to this overarching goal. Included is the search for and characterization of organics through mass spectroscopy, dust analyses, and infrared spectroscopy.
Europa lander: A lander will go even farther in addressing the specific nature of organics at Europa, in that a substantial sample of Europa's material could be directly ingested into a mass spectrometer on the surface. Additional spectroscopic techniques can robustly determine the nature of salts by being on the surface, complementary to the Europa Clipper's techniques.

How does the solar system work:
Europa Clipper: By understanding the geological, chemical, and atmospheric processes that operate at Europa, we will better understand the manifestations and variety of these processes, for comparison with other planetary bodies across the solar system, including Earth.
Europa lander: A lander will also contribute to understanding the fundamental processes that operate on solar system moons and planets. For example, if a lander carries a seismometer, its data about Europa-quakes would could be directly compared to seismic activity on Earth, the Moon, and Mars.

The Honorable Michael M. Honda
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
NASA - Ocean Worlds Hearing

1. During our hearing, we discussed how searching for signs of life and searching for planetary habitability for life are two different things. The planned orbiter and potential lander will analyze the habitability of Europa, which is different from detecting life or the signs of life. Should searching for the signs of life be a goal of the Europa Clipper mission? What would be required to actually search for life (and not just habitability) with the orbiter? Could secondary mission concepts for the Europa Clipper mission explicitly search for signatures of life – perhaps through the "handed-ness of amino acids"?

At present, we are in our infancy of understanding Europa. The first goal in understanding Europa as a potential abode for life is to understand whether it possesses the necessary ingredients for life: liquid water, chemical constituents from which to build organic molecules, and sources of chemical energy (nutrients) for life. In this way, understanding habitability is the first step. Directly searching for signs of life with an orbiter is much more difficult and risky, in that such is most effectively done after having sufficient knowledge of how Europa works to know what signs of life to look for and how best to do it.

To date, instruments for detecting life from an orbiter do not exist. To accomplish such a search from orbit would require specific knowledge that chemical biomarkers exist at Europa and are detectable at significant levels in its atmosphere or plumes. Such would also require technological advances in instrument hardware to analyze collected samples on the spacecraft in exquisite detail. It would be best to first understand whether detectable signatures of life plausibly exist at Europa, and then design the right instruments tuned to search for and detect those specific signs. Otherwise, we risk designing the wrong instruments, for a risky fishing expedition.

2. At the Ocean Worlds hearing, we heard that flying through a plume could enable instruments to look for life. Unlike on Enceladus, plumes on Europa seem to be fairly rare. NASA missions in the past have used impactors to create artificial plumes for studying – is this an option for Europa to increase the likelihood of flying through a plume with the orbiter?

It has not been demonstrated that an artificial impactor, of the mass that could be carried by the orbiter mission, could create a plume of sufficient height that the orbiter could fly through it at safe altitude. Moreover, an impact risks destroying the same volatile organic compounds that the orbiter would be attempting to detect. If organics are present in an artificially created plume, they may be well below the limits of instrumental detection. Finally, if an artificial plume could reach sufficient height, large particles could potentially pose a hazard for the orbiter. In summary, there is much uncertainty and risk associated with this approach.

3. When a lander is sent, will planetary protection be fully implemented, to avoid contaminating Europa with Earth-based extremophiles that could survive the long cold trip to Jupiter? How would performing this planetary protection impact the cost and timeline for a lander? How does this cost compare to an initial mission architecture of an orbiter with a secondary mission impactor that is designed to look for the signs of life?

Planetary protection will be a critical component of the Europa lander mission. Before launch the spacecraft and instruments will be subject to dry-heat microbial reduction (DHMR) and possibly additional techniques for sterilization and cleansing of the spacecraft. The spacecraft will then be loaded into a bio-barrier, which will isolate the clean spacecraft from any contaminants present in the launch vehicle and carrier spacecraft. Before deployment to the Europan surface the bio-barrier is removed, sending the sterile spacecraft to the surface.

Importantly, no known organism could survive the combination of conditions to which the lander will be exposed. The extremely cold (-280 F), desiccating, and intense radiation environment of the jovian system and Europa's surface will serve as additional insurance that Europa will not be contaminated. Some organisms, such as bacterial spores, can survive the cold and desiccating environment of space, but they cannot survive the radiation of the jovian system. Similarly, the few organisms that can survive intense radiation (such as the microbe *Deinococcus radiodurans*) can only do so in warmer conditions.

Also significant is that by merit of being battery powered, the current lander design does not provide any long-term, warm, microenvironments that could exist within a radioactive power source. Once the lander batteries have expired, the vehicle will continue to bake with a dose of approximately 2 krad per day on Europa's surface. This is an important contrast with the martian surface, where microenvironments and the near-subsurface could be transiently habitable for Earth microbes. On Europa, there is no place on the surface that is even remotely habitable by Earth standards.

The cost and timeline for implementing planetary protection for a Europa lander is currently under study. Over the past year we studied options for a lander or impactor launched with the flyby mission, but schedule risk to the flyby mission was determined to be too significant. Note that this schedule risk was not solely due to planetary protection; many factors contributed to this assessment. We are now studying a lander that would be launched separately from the flyby mission, thus decoupling the two schedules and eliminating any associated schedule risk to the flyby mission.

4. For decades, NASA and JPL have successfully explored planets and their moons through a three-step strategy of flyby, followed by an orbiter, and then followed by a lander. Each step on this journey builds on the knowledge gained through previous missions. This is designed to maximize the science return at each step, while minimizing scientific and technical risks to spacecraft, landers, and rovers. With respect to a Europa mission concept involving a lander, what provides the confidence that we know enough about the Europa surface to ensure that a lander will be placed in a scientifically compelling and safe site on the icy surface? Would

information gathered from an orbiter guide the physical design and structure of an ideal lander as well as influence the types of instruments that would be best to include?

Though the flyby, orbit, land sequence has been effective in the past, it becomes an inefficient strategy for exploration when questions of an astrobiological nature are driving goals for a mission. The search for life elsewhere ultimately requires *in situ* investigations that permit detailed chemical analyses of macroscopic samples that can be examined for biosignature molecules, and structures indicative of biology. Flyby and orbiting spacecraft are ideally suited for questions of a geological and geophysical nature, where mapping and global datasets can be coupled to understand surface and interior processes.

With astrobiology as a goal, reconnaissance for a scientifically valuable and safe landing site is critical, and the Europa flyby mission (Clipper) will return an incredibly valuable dataset for landing site assessment and selection. They key question then becomes: Do we need to wait until we have the data back from Clipper before we can design a scientifically useful and technologically robust lander? The brief answer is no. From a science standpoint the lander instrument payload would not likely change significantly based on the Clipper data – the centerpiece instrument is a Gas Chromatograph Mass Spectrometer (GCMS), which provides detailed chemical analyses of surface samples. GCMS instruments have been used on Mars and Titan for organic analyses and such an instrument would almost certainly be the instrument of choice for Europa's surface, as it is the 'workhorse' instrument for chemical analyses.

On the issue of technical design and mechanical configuration changes that would result from analyses of reconnaissance data, our studies show that even with the recon data, the engineering solution is likely to lead to a configuration similar to the highly robust tetrahedron design currently under study at JPL. The reason is that at the small scale (< 1 m) a lander should still be able to accommodate and tolerate surface variations. This is similar to the logic employed for the Mars Pathfinder and Mars Exploration Rover tetrahedron designs. Recon data might provide greater confidence that a legged lander could work, but it is not clear that there are any cost or risk savings with that architecture. Furthermore, if Europa is very dynamic and geologically active, then the recon data may be out of date if we try to use it a decade later – what if a new plume is erupting? What if new boulders have rolled downslope? We need to use the recon data in a relatively short cadence after it has been collected. In the scenario where lander design does not begin until after the recon data is collected, the lander would not get to Europa until the mid- to late 2030's, by which time Europa's surface at the desired landing site may have changed significantly.

5. To what extent would the inclusion of a lander, as part of NASA's initial planetary science mission to Europa, increase the risk of the mission being unable to successfully land on Europa's surface? For uncrewed science missions, has NASA previously attempted to (1) simultaneously launch both an orbiter and a separate lander in the same payload and (2) kept both of them simultaneously operating once the planetary destination was reached? In what ways could the uniqueness of such an initial Europa mission increase its overall mission risk?

The current concept for the first Europa lander mission is to launch it separately from the orbiter mission. The lander would be launched 1-2 years after the orbiter and would require 2-4 more

years to travel to Jupiter due to its larger launch mass. This separation allows the orbiter to arrive at Jupiter and perform its three-year primary science and reconnaissance mission prior to the lander arrival. Science data acquired by the orbiter will then be used to select an appropriate landing site based on a combination of science drivers and engineering considerations. The lander will be designed to accommodate a wide range of potential landing sites and will also include the ability to perform on-board hazard detection and avoidance during landing.

Even though we do not plan to launch the orbiter and lander in the same payload, NASA did conduct the Viking Program in exactly that fashion. Viking was our nation's first attempt to land on the surface of Mars and each mission included an orbiter and lander launched together. The Viking orbiters carried the landers into orbit and performed a set of required landing site reconnaissance observations. Those observations were used to pick the spot where the lander subsequently touched down. Simultaneous operations of both vehicles continued for several years, with the orbiter providing relay communications support to the lander.

6. To what extent could mission risks and total life cycle cost and schedule be reduced by making the initial Europa mission an orbiter without a lander? To what extent would the absence of a lander in the initial Europa mission reduce the amount of science discovery that would be possible in such an initial Europa mission?

As currently envisioned, the Europa Clipper mission will be conducted first and will be independent of a subsequent lander mission. Neither the orbiter design nor its primary mission science operations will be impacted by a follow-on lander. In other words, the potential for a lander mission does not increase the mission risk of an orbiter mission nor does it reduce the amount of science discovery possible. The schedule of the orbiter development and launch is als not impacted by the lander.

Adding a follow-on lander mission separate from the orbiter would increase overall life cycle cost because a separate launch vehicle and carrier vehicle is needed. The carrier vehicle brings the lander into Jupiter orbit and provides telecommunications relay support after landing. Fortunately, many of the hardware elements of the carrier are very similar to equivalent elements of the orbiter (i.e., propulsion, power, avionics, telecommunications, etc). Making use of these common elements through common procurements and integrated development teams will reduce the overall cost of the lander mission (provided that the lander carrier is completed in the same general time frame as the orbiter vehicle).

7. To what extent would the inclusion of the lander in the initial mission to Europa potentially jeopardize NASA's commitment to funding other planetary science efforts, especially during the peak cost period of the lander's development?

Maintaining a balanced portfolio of scientific targets, mission size, and competitive vs. directed missions is a high priority in the most recent Planetary Decadal Survey. As a result, NASA must ensure that an adequate rate of Discovery and New Frontiers missions occurs while simultaneously planning for Mars 2020, Europa Clipper, and a potential Europa Lander. Support from the Administration and Congress is needed to ensure that all of these high priority tasks can be conducted, but the opportunity exists to conduct ground-breaking science observations that

could demonstrate life developed beyond the Earth. This possibility would undoubtedly excite and inspire the public and is therefore a truly worthy goal for our nation's space agency.

Chairman John Culberson
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
NASA - Ocean Worlds Hearing
Dr. Jonathan Lunine

The Jupiter Europa mission was rated as the second highest priority flagship mission for the decade 2013-2022. This decadal survey, *Vision and Voyages for Planetary Science in the Decade 2013-2022* stated in part:

> *If NASA's planetary budget is augmented, then the program will also carry out the first in-depth exploration of Jupiter's icy moon Europa. This moon, with its probable vast subsurface ocean sandwiched between a potentially active silicate interior and a highly dynamic surface ice shell, offers one of the most promising extraterrestrial habitable environments in the solar system and a plausible model for habitable environments outside it. The Jupiter system in which Europa resides hosts an astonishing diversity of phenomena, illuminating fundamental planetary processes. While Voyager and Galileo taught us much about Europa and the Jupiter system, the relatively primitive instrumentation of those missions, and the low volumes of data returned, left many questions unanswered. Major discoveries surely remain to be made. The first step in understanding the potential of the outer solar system as an abode for life is a Europa mission with the goal of confirming the presence of an interior ocean, characterizing the satellite's ice shell, and enabling understanding of its geologic history.*

The Jupiter Europa mission science objective posited in this decadal was to "Explore Europe to investigate its habitability."

1. Please describe how the instruments selected for the Europa clipper mission will respond to this fundamental question: to "Explore Europe to investigate its habitability."

   The habitability questions are well addressed by the payload. Most of the instruments respond in some way to habitability. The following is a partial survey of what the instruments can do, identified by the instrument's acronym.
   MISE: The near-infrared spectrometer will search for and identify organic molecules that have been expressed onto the surface from the interior ocean, thereby telling us whether the molecules essential for life are in Europa's ocean. It will also identify the particular compositions of the salts that we strongly suspect (from Galileo) are on the surface, which will help determine the specifics of the habitability of the ocean.
   EIS: These cameras will be able to image at very high resolution a wide range of geologic features on the surface, including those that might indicate places where liquid water has come out onto the surface. Such places will be excellent sites for a lander to conduct its habitability investigations. The color filters on the camera will also aid in organic and salt identification. Finally, the EIS cameras will look for evidence of plumes which, if they exist, would be places to sample to get more detailed information on habitability.
   UVS: The ultraviolet spectrometer will be a key instrument for detecting the presence of a plume and measuring the composition of the atoms and some molecules in the plume gas—one way to assess whether the ocean is more than just salty water..
   MASPEX and SUDA: These two mass spectrometers can measure atoms, molecules and dust lofted from the surface by evaporation and sputtering, even in the absence of a plume, which will allow yet another way of detecting the presence of surface organics and salts. If there is a plume (or plumes), then these same measurements performed within the plume may tell us more directly about the subsurface ocean.
   RMS: The radiation monitoring instruments will allow a specification of the influx of particle energy to the surface, energy that may produce peroxides (from the ice) that could serve as an energy source for life in the ocean.

Note that the lander provides a completely different dimension of exploring for habitability, including and especially looking for evidence of life in deposits on the surface. Thus Clipper and Lander are very much complementary.

2. Please describe how the science instruments selected for the orbiter/clipper mission will "confirm the presence of an interior ocean, characterize the satellite's ice shell, and enable understanding of its geologic history." (Paraphrase from decadal survey.)

This is again a partial list composed from my own knowledge of the mission, rather than a paraphrase from the decadal survey itself.:

REASON: This radar will probe through the ice crust, potentially reaching (in areas of thinner ice) right down to the ocean. This will allow measurement of the depth to the ocean, as well as detection of potential lenses of liquid (or recently-liquid) water suspended near-surface in the crust.

MAG-PIMS: This combined instrument will sense the ocean through the latter's effect on the Jovian magnetic field surrounding Europa, but in a much more sensitive and well-calibrated way than did the Galileo orbiter in the 1990's. The sensitivity of the new instrument will allow the saltiness of the ocean to be determined.

EIS and MISE will use their imaging and spectral capabilities to map the geology of the surface in great detail, allowing the history of the crust and its interaction with the ocean to be constrained.

THEMIS: This thermal mapper will look for warm spots in the crust of Europa indicating where liquid water may have been or continues to be injected into the crust. It will also tell us how warm are the fractures on the surface and hence how close the ocean is to the surface in those regions. MISE will do a similar task, for especially high temperature hot spots (if they exist).

GRAVITY: Measuring subtle speed changes of the spacecraft (done by messuring the doppler shift of the transmitted radio signal from Clipper) as it repeatedly flies past Europa will allow the depth to the ocean to be constrained as well as the overall structure of Europa's interior.. This complements the other ways to determine depth and is especially useful where the crust may be thick and hence difficult or imnpossible to penetrate with the REASON radar.

The planetary decadal survey continued with the following:

Current State of Knowledge and Important Science Questions

The deep-rooted motives underlying the planetary sciences address issues of profound importance that have been pondered by scientists and non-scientists alike for centuries. Such questions cannot be fully addressed by a single spacecraft mission or series of telescopic observations. It is likely, in fact, that they will not be completely addressed in this decade or the next. To make progress in organizing and outlining the current state of knowledge, the committee translated and codified the basic motivations for planetary science into three broad, crosscutting themes:

• *Building new worlds—understanding solar system beginnings*
— How did the giant planets and their satellite systems accrete, and is there evidence that they migrated to new orbital positions? Important objects for study: Enceladus, Europa, Io, Ganymede, Jupiter, Saturn, Uranus, Neptune, Kuiper belt objects, Titan, and rings.

• *Planetary habitats—searching for the requirements for life*
— What were the primordial sources of organic matter, and where does organic synthesis continue today? Important objects for study: comets, asteroids, Trojans, Kuiper belt objects, Enceladus, Europa, Mars, Titan, and uranian satellites.

--Beyond Earth, are there contemporary habitats elsewhere in the solar system with necessary conditions, organic matter, water, energy, and nutrients to sustain life, and do organisms live there now? Important objects for study: Enceladus, Europa, Mars, and Titan.

• *Workings of solar systems—revealing planetary processes through time*
--How have the myriad chemical and physical processes that shaped the solar system operated, interacted, and evolved over time? Important objects for study: all planetary bodies.

3. Please describe how a Europa clipper and lander mission will address the Current State of Knowledge and Important Science Questions outlined by the decadal committee:
    - understanding the solar system beginnings
    - searching for the requirements necessary for life, and
    - how does the solar system work

The second bullet has been addressed in the answer to question 1. The other two bullets require a very extensive essay (indeed a long article) for a satisfactory answer. My answer below is, of necessity, not complete. There are narratives in the decadal survey itself that provide partial answers.

For the first bullet: Briefly, Jupiter's Galilean moons (of which Europa is one) form a kind of "miniature solar system" with the least icy moon (Io, all rock and metal) closest to Jupiter, and the most ice-rich (Ganymede and Callisto) farthest out. This is the same pattern we see in the solar system at large, where the inner portion is all rocky planets (Mercury, Venus, Earth, Mars) while the outer solar system is full of water ice (and, of course, gas, in the form of the giant planets themselves). Having two examples to study in detail –Jupiter's moons and the solar system overall—provides us with a much more powerful opportunity to understand how this progression is established than the solar system by itself. And just as important, why is the progression from small rocky planets to icy and gaseous planets not seen in most other planetary systems? And why are the moons of Saturn not similarly arranged from rockiest to iciest, like Jupiter's?

By studying Europa in detail, including its internal structure and the nature of the surface salts, we can constrain the size and density of its rocky core and determine (to some limited extent) how much it resembles samples of primitive rocky material in the solar system (carbonaceous chondrites, for example). By detecting and measuring noble gases in the tenuous Europan atmosphere (or on its surface), we have a comparison with the noble gas abundances in other solar system bodies. Likewise with the isotopes (flavors of elements distinguished by the number of neutrons) of major elements like carbon (C), nitrogen (N) and oxygen (O): if we can measure them on Europa, we can compare them with other solar system bodies to see if the starting material was the same throughout the solar system. Are the noble gases and isotopes of C,N,O on Europa's

surface (or in its plume) similar to what is seen in meteorites, or are the abundances very different? This will tell us the extent to which material in the primitive early solar system may have been reprocessed around Jupiter as Jupiter formed.

There is much more detail to the story than this, but the above should provide a flavor for how studying Europa addresses some questions regarding how the solar system formed.

For the third bullet: The solar system is rich in natural phenomena we cannot explore on Earth. Every object we study in the solar system provides a new environment in which to study the interplay of physics, chemistry, geology (and eventually, biology), both to better understand active phenomena and to trace the history of the solar system. To give one example: Europa has a very young surface, and so the history of the solar system is not recorded in a densely cratered surface as is the case for our Moon, or Callisto. But Europa is special because tidal heating is sustaining a subsurface ocean, the subsurface ocean is distorting Jupiter's magnetic field in the vicinity of Europa (in a way we can measure), and Jupiter's magnetic field is causing electrons, protons, and other subatomic particles to slam into Europa's surface at very high speed. It is a very complex but very tightly interconnected system, powered by Jupiter's gravitational and magnetic fields. Studying these phenomena in detail with Clipper and Lander will therefore provide deep insight into the physics and chemistry of these processes under conditions difficult or impossible to replicate anywhere on Earth.

The Honorable Michael M. Honda
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
NASA - Ocean Worlds Hearing

1. During our hearing, we discussed how searching for signs of life and searching for planetary habitability for life are two different things. The planned orbiter and potential lander will analyze the habitability of Europa, which is different from detecting life or the signs of life. Should searching for the signs of life be a goal of the Europa Clipper mission? What would be required to actually search for life (and not just habitability) with the orbiter? Could secondary mission concepts for the Europa Clipper mission explicitly search for signatures of

life – perhaps through the "handed-ness of amino acids"?
My view is that the goals of the Europa Clipper (which is actually not an orbiter but rather a repeat-flyby mission) are well established and scientifically sound. Trying to detect life with Clipper would require that a plume be present that the instruments could adequately sample, which cannot be guaranteed. Handedness, for example, requires direct sampling of fresh ocean material, which Clipper can only access in a practical fashion by flying very low through a plume—if a plume exists. Habitability, on the other hand, can be very well addressed with Clipper whether or not plumes are present. The Lander, on the other hand, can have as one of its goals the search for life because evidence for life may be present in deposits of material effused from cracks and vents onto the surface. If the Lander can be properly navigated to such a site, guided by data from Clipper, then life detection is a practical goal for its mission.

2. At the Ocean Worlds hearing, we heard that flying through a plume could enable instruments to look for life. Unlike on Enceladus, plumes on Europa seem to be fairly rare. NASA missions in the past have used impactors to create artificial plumes for studying – is this an option for Europa to increase the likelihood of flying through a plume with the orbiter?

   I am skeptical that an artificial plume is an appropriate way to sample the ocean, which is the potentially habitable environment of interest on Europa. An impactor large enough to smash through hundreds of meters of crust to release the ocean into space seem implausible for a planetary mission. The extreme energies would destroy the very molecules we seek to study, and the mixing of vaporized/liquified crust with the ocean material would make the debris difficult to interpret.

3. When a lander is sent, will planetary protection be fully implemented, to avoid contaminating Europa with Earth-based extremophiles that could survive the long cold trip to Jupiter? How would performing this planetary protection impact the cost and timeline for a lander? How does this cost compare to an initial mission architecture of an orbiter with a secondary mission impactor that is designed to look for the signs of life?

This witness is not qualified to answer question 3, and so this is referred to Dr. Elachi. My experience with NASA missions gives me full confidence that planetary protection will be fully implemented.

4. For decades, NASA and JPL have successfully explored planets and their moons through a three-step strategy of flyby, followed by an orbiter, and then followed by a lander. Each step on this journey builds on the knowledge gained through previous missions. This is designed to maximize the science return at each step, while minimizing scientific and technical risks to spacecraft, landers, and rovers. With respect to a Europa mission concept involving a lander, what provides the confidence that we know enough about the Europa surface to ensure that a lander will be placed in a scientifically compelling and safe site on the icy surface? Would information gathered from an orbiter guide the physical design and structure of an ideal lander as well as influence the types of instruments that would be best to include?

The Europa Clipper, which will do repeated flybys of Europa, is well instrumented to provide landing site identification and certification for a lander. The high resolution cameras and other instruments are capable of identifying safe and scientifically interesting landing sites on Europa. Under the present plan, the lander is being designed in parallel with Clipper, and so its design must be based on our current knowledge of Europa (from Galileo), and on a design philosophy that provides for a robust capability in landing safely. Based on what we know from Galileo, it is my personal opinion that this is certainly possible.

Questions 5,6,7 are outside the expertise of this witness and will be left to Dr. Elachi.

5. To what extent would the inclusion of a lander, as part of NASA's initial planetary science mission to Europa, increase the risk of the mission being unable to successfully land on Europa's surface? For uncrewed science missions, has NASA previously attempted to (1) simultaneously launch both an orbiter and a separate lander in the same payload and (2) kept both of them simultaneously operating once the planetary destination was reached? In what ways could the uniqueness of such an initial Europa mission increase its overall mission risk?

6. To what extent could mission risks and total life cycle cost and schedule be reduced by making the initial Europa mission an orbiter without a lander? To what extent would the absence of a lander in the initial Europa mission reduce the amount of science discovery that would be possible in such an initial Europa mission?

7. To what extent would the inclusion of the lander in the initial mission to Europa potentially jeopardize NASA's commitment to funding other planetary science efforts, especially during the peak cost period of the lander's development?

TUESDAY, MARCH 15, 2016.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WITNESS

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

CHAIRMAN'S OPENING REMARKS

Mr. CULBERSON. The Commerce, Justice, Science Appropriations Subcommittee will come to order. I want to welcome our witness, General Bolden, and thank you for your service to the country, General Bolden. For your service to NASA, to the space program, and for keeping us all safe and free and strong for your service in the United States Marine Corps as well. And this has just occurred to me, today may be your last hearing here in front of us. I want to thank you very much again for your service. And what a privilege it has been for us to work with you, to help make sure the American space program is the best in the world, has been, always will be.

This committee and the Congress has been committed to the American space program. We and the Congress and the country have given the space program all the support that you need. We have often given you too much on your plate and not enough money to do so. But in this year's 2016 appropriations bill, as you know, we made certain that you for the first time have got the resources you need to do what is on your plate to ensure that we never surrender the high ground of outer space to any other nation. And we will continue to do so. The Congress and the country strongly support what you and your colleagues at NASA are doing, General Bolden.

We today in our hearing are going to discuss the 2017 appropriations bill and what NASA's needs are for 2017. I am actually going to minimize any discussion, frankly General Bolden, of the President's fiscal year 2017 budget request because quite frankly it is, I have to say that President Obama's budget request is frankly almost embarrassing. We cannot and will not even consider a budget request that would ask this Congress to cut NASA's funding. We cannot consider a budget request that contains $763 million in unauthorized mandatory fees and taxes and things that just are not going to happen.

We, all of us in this committee, admire you and the great men and women at NASA immensely. We will certainly talk about the President's budget request but it is not realistic. It is not going to happen. And I cannot imagine anyone in this Congress seriously considering it. And I am actually glad we have got language in the 2016 appropriations bill and the 2015 bill and we will have it again in this bill that says no agency of the Federal government can

change any funding level for any policy or program based on the President's budget request. That the agencies have to follow the appropriations bill, because that is what matters, it is the will of Congress as signed into law by the President. And we know that, and you cannot really comment on this, but I know you are as disappointed as we are in the President's request. We love what you do at NASA and we are going to be here to support you, sir. And we will make certain that we are going to do our very best in this tough budget environment to be sure that NASA has got the resources that you need to do your job. Because, you know, the bottom line is this request that we have received from the White House is essentially a $1.023 billion cut to NASA's budget which is just not going to happen. We are not going to let that happen.

We have in this budget year in the—you know, it really is baffling. It is hard for me to find the words to describe it. And it is not your fault, General Bolden. You do a superb job. The men and women at NASA do a great job. But it is very difficult for us to get our arms around the fact that the White House would actually expect the Congress to cut NASA by over $1 billion and has not given us, not given you the support that you need, sir.

Also I think it is important to note that NASA has just accepted a new group of applications for just 14 spots in your 2017 class of astronauts, an indication of the level of support the country has for the work that you do. They had over 18,300 applications for 14 spots as astronauts. That is a record that surpasses the previous 1978 record of 8,000 applications. And it is an indication, I think, of the level of support the country has for the work that you do. Every time there is a new space mission, a new landing, a new launch, the NASA website becomes one of the most popular in the country. There is just a tremendous amount of support out there for what you do. And it just continues to be baffling to us as to why the Office of Management and Budget refuses to give you the support that we think you deserve.

But this subcommittee will make sure that you get the resources that you need. Again, this is going to be a tough budget year and we will be right there behind you, sir, every step of the way. And before we proceed I would like to recognize Mr. Honda for any remarks he would like to make.

RANKING MEMBER OPENING REMARKS

Mr. HONDA. Well thank you, Mr. Chairman, and welcome, Administrator Bolden, and thank you for being here today. It is good to see you again.

Let me just take a moment to thank you again for the great visit we had a couple of weeks ago at NASA Ames. You and I spent the better part of a day together, for me an unprecedented over five hours. And that was really cool. And I really appreciate the effort the Ames family went to to accommodate the visit and highlight some of the amazing groundbreaking work that the scientists and engineers are performing at Ames in support of this mission, NASA's mission.

And Mr. Chairman, perhaps you and I can go on a tour of NASA Johnson down near your home in Houston, Texas. I have still been waiting for an invitation. But you know, I am patient. Perhaps we

can all organize a trip for the subcommittee to Goddard or JPL. And I would love to meet more of the NASA family and see firsthand some of the other great work being performed around the country.

Administrator Bolden, as you know Chairman Culberson and I share the same passion for science and I love it when he starts talking about we are going to get you more money, we are going to get you more money. He sounds just like a great Democrat, you know? But actually this is not a partisan issue. It is about a national priority and moving us forward in the whole arena of knowledge and pursuing knowledge, that which we know and that which we are seeking. So this passion is also evident in last year's final budget that included the healthiest top line NASA has seen in many years. And I just want to thank you, Mr. Chairman, for that.

This year I am looking forward to building on our work from last year and continuing robust support for NASA and a wide variety of missions from exploring our neighboring worlds and probing the creation of the universe, to improving our understanding of our own planet and working with commercial partners to strengthen America's presence in space and supporting the burgeoning commercial space industry which is constantly growing. That being said, I share my colleague's frustrations with this year's proposed discretionary budget from the President that recommends scaling back our support for NASA by reducing NASA's discretionary top line by $1 billion. I will be more accurate, the Chairman said $1.3 billion. And so we are going to be working together on this. This is the time to be investing in NASA, not selling it short. At the same time, I must also urge my colleagues to support an overall level of non-defense discretionary resources that would allow us to provide a healthy budget for NASA overall.

Americans are really inspired by the successes and breakthroughs of NASA and our commercial partners, be it the amazing photos of Pluto captured by New Horizons, Scott Kelly's triumphant year in space, or the successful first stage landings of SpaceX and Blue Origin rockets. Americans are captivated by space and NASA.

Movies like "The Martian," "Gravity," "Interstellar," tap into this public support and help fan the flames of support. And nothing highlights this more than the record shattering, as it was said, 18,300 applicants who applied to become a NASA astronaut last month. You said 14-point-what? How many spots?

Mr. CULBERSON. Fourteen spots.

Mr. HONDA. Fourteen spots. I thought you said 14.3, and I was wondering who the 0.3 was going to be. And so what I will be interested in is if there is a way we can get some information on the demography of the applicants, who they are, where they are from, you know, all that sort of interesting, as an educator I would be interested in the source and where they were coming from.

So I look forward to hearing your testimony this morning and to learn more about NASA's programs and how NASA is going to capitalize on this strong public interest and create the most impactful and inspiring missions to both improve life on Earth and push our frontiers further out into the cosmos.

Mr. Chairman, thank you.

Mr. CULBERSON. Thank you. Thank you, Mr. Honda. General Bolden, we really do appreciate your service. Thank you for being here today. And without objection, your written statement will be entered into the record in its entirety. And we welcome your summary of your testimony. If you can do so within approximately five minutes or so it would be great.

ADMINISTRATOR'S OPENING REMARKS

General BOLDEN. Yes, sir. I will do my best. And Mr. Chairman and members of the subcommittee, it is my extreme pleasure and it is actually an honor for me to be here today to discuss with you President Obama's $19 billion fiscal year 2017 budget request for NASA. And I, it is unusual for me to do this. But because there are young students here, I want them to go back understanding how this process works. And I think you mischaracterize me when you say that I am disappointed in the President's budget. I am not. I helped to craft it. And I am very proud of that budget. And we will discuss in this hearing how we got there and then the process that you all are going to use to give us the funds that we finally get in appropriations. Because what they should take away is that the President proposes, which means it is a proposal, and the Congress disposes, which means you all give us the money. And as you said, that is what becomes the budget. So I did not want them to go away thinking that the NASA Administrator was not happy with the President's budget, because I am. We worked really hard to bring you that budget. So now I have wasted a lot of my time.

This request builds on the outstanding fiscal year 2016 NASA appropriation that this Congress gave us last year. And I mean it when I say it was an outstanding budget. $19.3 billion is not chump change. And we really want to be able to extend what that budget allows us to do, and that was the way we crafted the 2017 budget. I want to thank you again, Mr. Chairman, personally for your leadership in crafting the 2016 budget.

So it is my honor to serve as the NASA Administrator throughout the Obama administration. And as we submit what is likely, as you mentioned, my final budget, I am also proud of the many things this agency has accomplished on behalf of the American people with the resources the President and Congress have committed to us over the past seven years. Together we have enabled our nation to continue leading the world in space exploration and scientific discovery.

Two weeks ago American astronaut Scott Kelly returned home from the International Space Station after 12 months working off the Earth for the Earth. His year in space will pay scientific and medical dividends for years to come, helping pave the way for future astronauts to travel to Mars and beyond. Commander Kelly significantly advanced our journey to Mars and I trust that you join me in saluting his service to our nation.

NASA is closer to sending American astronauts to Mars than at any point in human history and this budget will keep us moving forward. The support of this committee and Congress is essential to this journey. The International Space Station is the cornerstone of our exploration strategy. Thanks to the determination and ingenuity of American industry, we have returned Space Station cargo

resupply launches to U.S. soil, insourced jobs, and helped establish a new private market in low Earth orbit. American companies are now ferrying supplies to our astronauts on the Space Station from the United States with Orbital ATK set to launch again later this month, in fact next week, and SpaceX targeting a resupply mission in early April, both from the Kennedy Space Center.

In July Orbital will conduct a return to flight mission from the Wallops Flight Facility. Thanks to the administration's decision to invest in American industry and to this committee's full funding in last year's budget, Boeing and SpaceX continue to make great progress toward certification in 2017 to safely transport our astronauts to the Space Station from U.S. soil, ending our sole reliance on Russia once and for all.

NASA is making significant progress on the journey to Mars, developing our newest, most powerful rocket ever built, the Space Launch System, and the Orion Crew Vehicle as part of a sustainable and affordable deep space exploration system. This budget supports the Agency's baseline commitment for an uncrewed test flight of SLS and Orion in 2018 and a crewed flight by 2023. With additional funding provided by Congress, the teams are working toward an earlier launch date for the first crewed mission and are already designing and procuring long lead hardware for subsequent missions.

The budget also increases funding for habitation systems development, a key component of our stepping stone strategy to send humans to Mars.

The President's budget funds a robust science program with dozens of operating missions studying our solar system, the universe, and the most important planet in our solar system, Earth. This coming July 4th, Independence Day, the Juno spacecraft will orbit Jupiter while the Cassini spacecraft will prepare to execute its dramatic grand finale orbits of Saturn. OSIRIS–REx will launch to a near-Earth asteroid to collect samples for return to Earth in 2023. In 2017 and 2018 NASA will launch seven exciting space science missions, including the James Webb Space Telescope. Before we send humans to Mars robots are paving the way, with Mars InSight now targeted for launch in 2018. Another Mars rover set to launch in 2020, joining the Curiosity and Opportunity rovers now exploring the red planet, and work underway to define the next Mars mission for 2022.

We are formulating missions to explore Jupiter's moon Europa, as well as WFIRST, designed to study dark energy, perform galactic and extragalactic surveys, and explore exoplanets.

We are accelerating the building of LANDSAT 9 as part of our sustainable land imaging architecture to continue our over 40-year record of high quality measurement of Earth's land cover.

NASA technology drives exploration. With this request, NASA will continue to conduct rapid development and incorporation of transformative space technologies to enable future human and robotic missions, increase capabilities of other U.S. agencies, and address aerospace industry challenges. Space technology investments will ensure that we continue to lead the world in exploration and scientific discovery.

NASA's aeronautics program advances U.S. global leadership by developing and transferring key enabling technologies to make aviation safer, more efficient, and more environmentally friendly. With this request, NASA aeronautics is ready to take the next step to develop and fly X-plane demonstrators in partnership with industry and academia, including ultra-efficient subsonic transport experimental aircraft and the world's first low boom supersonic flight demonstrator.

Mr. Chairman, we appreciate the strong and consistent support we have received from this committee. I look forward to your questions.

[The information follows:]

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BY WITNESS
March 15, 2016

Statement of

The Honorable Charles F. Bolden, Jr.
Administrator
National Aeronautics and Space Administration

before the

Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
U.S. House of Representatives

Mr. Chairman and Members of the Committee, I am pleased to have this opportunity to discuss NASA's FY 2017 budget request. The President is proposing an FY 2017 budget of more than $19 billion for NASA, building on the strong and consistent support NASA has received from this Committee and the Congress. This request, which includes both discretionary and mandatory funding, will allow NASA to continue to lead the world in space through a balanced program of exploration, science, technology, and aeronautics research.

Of note, within this request, NASA is proposing a ten-year plan that would significantly accelerate aeronautics research. We seek support from congress for a substantial increase in funding for aeronautics that will support a vigorous flight demonstration program to demonstrate and validate technologies to dramatically improve the aircraft of the future. We are ready to test these technologies and concepts as integrated systems by developing "X-plane" demonstrators. The United States leads the world in aviation, but this leadership can only be maintained by a vigorous program of research to create the efficient aircraft of the future.

NASA is positioned for a vibrant future, and we look forward to the long term support that will enable the Agency to continue leading the world into space and on the journey to Mars. We are on track for the key near-term steps on that journey with flight certification of our commercial crew transportation systems in 2017, and the launch of Exploration Mission 1 (EM-1) in 2018. In 2016, the Juno Spacecraft will orbit Jupiter while Cassini will execute its dramatic "Grand Finale" orbits of Saturn. The Solar Probe Plus (SPP), Transiting Exoplanet Survey Satellite (TESS) and the James Webb Space Telescope (JWST) are on track to launch in 2018, and a new Mars rover is in development for a 2020 launch on its way to join the spectacular Curiosity rover now exploring the planet. NASA's missions are providing the critical data we need to understand the home planet, our nearby star, every planet in the Solar system, and the universe. We are accomplishing all this while consistently improving program performance: GAO reports that overall development cost growth for the portfolio of major development programs it tracks, excluding the James Webb Space Telescope (JWST), fell to 1.3 percent, at or near the lowest levels we have reported since GAO began annual reviews in 2009. Relying on the consistent support of Congress, the Agency remains on a sustainable path to accomplish a world-leading program of exploration and discovery in space. The Agency is well positioned to continue on its long-term mission, and, by focusing on executing the plan we have laid out, we intend to earn the continued support of future Administrations and Congresses for this plan.

Human Exploration and Operations

The FY 2017 President's Budget Request continues NASA's Journey to Mars, extending our reach in space with the specific goal of sending human missions to Mars, and the broader aim of establishing a sustainable human presence beyond Earth. NASA's exploration strategy is to evolve from today's Earth-reliant posture to conducting missions in the Proving Ground of cislunar space and then to the Earth-independent capability needed to extend human presence into the solar system and to the surface of Mars. The FY 2017 request includes $3,336.9 million for Exploration, with $2,859.6 million for Exploration Systems Development, and $477.3 million for Exploration Research and Development. The FY 2017 request also includes $5,075.8 million for Space Operations, including $1,430.7 million for the International Space Station (ISS), $887.4 million for Space and Flight Support, and $2,757.7 million for Space Transportation – both commercial crew system development and on-going crew and cargo transportation services that resupply ISS.

The first step on the Journey to Mars is our current activity in low Earth orbit (LEO), where research and technology development activities conducted aboard ISS are delivering the knowledge we need to keep our astronauts safe, healthy and productive on deep-space missions of increasing durations. ISS research is advancing the fundamental biological and physical sciences for the benefit of humanity, improving life on Earth and adding to our understanding of the universe. The ISS is the cornerstone of our exploration strategy, a nearby outpost in space where humanity is taking its early steps on its journey into the solar system, and we appreciate the action Congress took last year to authorize continued Station operations through at least 2024, consistent with the President's request.

Under the Commercial Resupply Services (CRS) contracts, our two commercial cargo partners, Space Exploration Technologies (SpaceX) and Orbital ATK, have demonstrated not only the ability to provide cargo deliveries to ISS, but also the flexibility to recover effectively from mishaps. Both companies have worked closely with NASA to understand the anomalies they experienced over the last year and a half. In developing the launch vehicles for their cargo spacecraft, SpaceX and Orbital ATK have also helped to bring some of the commercial satellite launch market back to the U.S., and helped to lower commercial launch costs. This January, through CRS-2, NASA contracted with SpaceX, Orbital ATK, and Sierra Nevada Corporation to ensure that critical science, research and technology demonstrations will be delivered to the ISS from 2019 through 2024. Our commercial crew partners, SpaceX and the Boeing Company, are developing the Crew Dragon and CST-100 Starliner spacecraft, respectively. The work, being done under two Federal Acquisition Regulation (FAR)-based, fixed-price Commercial Crew Transportation Capability (CCtCap) contracts, is expected to result in flight certification of their crew transportation systems by the end of calendar year 2017. In 2015, NASA ordered the initial post-certification missions, and in 2016, milestone completion and work are progressing well. 2017 will be an exciting and challenging year as we work with our partners to launch the first new human spaceflight capability in a generation.

Under the auspices of the ISS National Laboratory, managed by the Center for the Advancement of Science In Space (CASIS), NASA is encouraging broader use of the ISS by non-traditional companies and other Government agencies. The ISS National Lab has reached full capacity for allocated crew time for research that was both scientifically and economically reviewed for terrestrial benefit.

As we move out into the Proving Ground of cislunar space, we will employ new deep-space systems, including the heavy-lift Space Launch System (SLS), Orion crew vehicle, the Exploration Ground Systems (EGS) that support them, and new deep space habitation capabilities developed through public-private partnerships. We will also continue to invest in exploration research and development that will make future missions safer, more reliable, and more affordable. NASA's initial deep-space mission,

EM-1, is on track to launch to a distant retrograde orbit in the Proving Ground around the Moon in 2018. In 2015, the Agency conducted a key decision point review of the Orion program, establishing an Agency baseline commitment level for Orion that supports a 2023 launch readiness date for EM-2. The FY 2017 budget fully funds the Agency baseline commitment level. In the initial phase of our Proving Ground operations, NASA will use this region of space to test and demonstrate flight and mission operations and staging of human-rated vehicles farther from Earth than ever before. Crewed Orion missions launched on the SLS in the 2020s will establish our capability to operate safely and productively in deep space.

SLS and Orion are critical to human spaceflight beyond LEO. The NASA-Industry teams building SLS and Orion have made tremendous progress over the last year in building and testing vehicle components. For SLS, the Core Stage qualification and EM-1 flight barrels are awaiting vertical welding at the Michoud Assembly Facility (MAF), the RS-25 flight engines are all assembled and awaiting engine controller installation, and production of the final booster qualification motor is nearly complete. For Orion, the EM-1 Crew Module pressure vessel welding is complete, the European Service Module structural testing is in progress, and software testing is underway in the Integrated Test Lab. In EGS, Mobile Launcher structural mods are complete, the Vehicle Assembly Building High Bay 3 platforms are being installed, and Crawler Transporter mods are underway.

Subsequent missions in the Proving Ground will target challenges and strategic knowledge gaps while helping develop the core capabilities necessary to expand human activity farther into deep space, culminating in demonstration of a long-duration (one-year plus) deep-space habitation capability, critical preparation for crewed missions to Mars. The FY 2017 request includes the funding to support work on the required habitation systems. Our FY 2017 budget includes $90 million to support habitation systems development. This work includes the second phase of the Next Space Technologies for Exploration Partnerships (NextSTEP) Broad Agency Announcement, an effort to stimulate deep-space capability development across the aerospace industry. Through these initial public-private partnerships, NextSTEP partners will provide advanced concept studies, technology development projects, and significant measurements in key areas, including habitat concepts, environmental control and life support systems, advanced in-space propulsion, and small spacecraft to conduct missions related to Strategic Knowledge Gaps. The NextSTEP efforts are a key component of our overall strategy to move into the Proving Ground.

NASA will continue to develop the Asteroid Redirect Mission. This will include a robotic mission that will remove a multi-ton boulder from a target asteroid and use solar-electric propulsion to move the boulder into lunar orbit. A human mission using the SLS and Orion vehicles will then rendezvous with and take samples from this asteroidal mass. The mission demonstrates the use of advanced solar-electric propulsion, automated rendezvous and complex crew operations in the Proving Ground of lunar orbit, and improves NASA's ability to identify and respond to potentially dangerous asteroids.

Space Technology

NASA's FY 2017 request includes $826.7 million for Space Technology to conduct rapid development and incorporation of transformative space technologies to enable NASA's future missions, increase the capabilities of other US agencies, and address aerospace industry challenges. NASA's Space Technology program has developed a diverse portfolio creating a technology pipeline to solve the Agency and Nation's most difficult challenges in space. Space Technology will continue to prioritize "tipping point" technologies and early-stage innovation with approximately 600 awards to industry and small businesses, private innovators, and academia to spark new ideas for the benefit of NASA as well as the broader US aerospace and high tech sectors. As efforts complete, appropriate technologies will be transferred and commercialized to benefit a wide range of users ensuring the nation realizes the full economic value and societal benefit of these innovations. Technology drives exploration by continuing maturation of enabling

technologies for future human and robotic exploration missions including deep space optical communications to return more data and improve operations; improved carbon dioxide removal and oxygen recovery systems for more efficient life support and environmental control capabilities; nuclear thermal propulsion technologies for rapid in-space transit; robotics and autonomy to reduce mission cost and risk; and advancements in remote sensing instruments and spacecraft subsystems to reduce size, weight and power requirements enabling lower cost missions utilizing small spacecraft.

The program will take a major step early next year with the launch of the Green Propellant Infusion Mission (GPIM). GPIM will demonstrate on-orbit a propellant that has higher performance and is much safer to handle than the hydrazine fuel that is now commonly used for in-space propulsion systems.

In FY 2017, building on the Robotic Refueling Mission technology demonstrations on ISS, the program will continue mission formulation for Restore-L, a mission to advance and demonstrate the capability to service and refuel satellites on orbit with the potential to add life to existing satellites worth billions of dollars.

In support of the Asteroid Redirect Robotic Mission (ARRM), Space Technology continues development of high-powered solar electric propulsion technologies that will enable extremely efficient orbit transfer and accommodate increasing power demands for government and commercial satellites.

Also in FY 2017, the Mars Oxygen In Situ Resource Utilization Experiment (MOXIE) payload on the Mars 2020 mission will hold a Critical Design Review. The payload will demonstrate the in situ production of oxygen on Mars, a technology that could furnish oxygen for breathing and fuel on future Mars missions. The Laser Communications Relay Demonstration project will complete its Critical Design Review and Key Decision Point - C, and will continue hardware fabrication to support a late CY 2019 launch readiness date.

Science

NASA's science vision is to use the vantage point of space to achieve with the science community and our partners a deep scientific understanding of our home planet, the Sun and its effects on the solar system, other planets and solar system bodies, the interplanetary environment, and the universe beyond. The President's FY 2017 budget requests $5,600.5 million for NASA's Science program including $2,032.2 million for Earth Science, $1,518.7 million for Planetary Science, $781.5 for Astrophysics, $569.4 million for the James Webb Space Telescope, and $698.7 million for Heliophysics.

From orbit, NASA satellites advance our knowledge of our dynamic and complex home planet, Earth. In addition to driving scientific discoveries, NASA Earth-observing research satellite missions collect essential measurements that serve national interests. Our NASA satellites monitor regional and global food and water security and air quality, support disaster response, and contribute to economic growth. Nineteen NASA research missions – five of which were launched in a span of 11 months from 2014 to 2015 – are orbiting the Earth and providing key measurements today. The Global Precipitation Measurement mission has already produced the first global rain and snowfall map, and the constellation routinely observes precipitation over the entire globe every 2-3 hours. The ISS Rapid Scatterometer, the first science payload to be robotically assembled in space since the ISS itself, measures surface ocean wind speeds and directions. And the Soil Moisture Active and Passive mission provides global, high-accuracy soil moisture and sea-surface salinity measurements at 35 km resolution.

In 2016, three launches will add significantly to our capabilities. On January 17, NASA launched the Jason-3 satellite, a mission led by NOAA and EUMETSAT, along with our French partner CNES. Jason-3 is the fourth mission in a U.S.-European series using precision altimetry to measure ocean surface

topography – the hills and valleys of the ocean surface. Later in the year, the SAGE-III (Stratospheric Aerosol and Gas Experiment-III) instrument will launch to the ISS to obtain atmospheric trace gas profile data, including ozone measurements, with the Lightning Imaging Sensor as a secondary payload. In October, a constellation of eight micro-satellites called the Cyclone Global Navigation Satellite System (CYGNSS) will become NASA's first Earth Venture Mission small-sat constellation, to investigate the evolution of tropical cyclones and hurricanes. The FY 2017 request supports development of new missions including the Ice, Cloud, and land Elevation Satellite-2 (ICESAT-2) and the Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) that provide continuity for key long-term measurements.

NASA is building Landsat 9 as part of our Sustainable Land Imaging (SLI) architecture that will continue our Nation's accurate measurement of Earth's land cover. NASA and the U.S. Geological Survey (USGS) initiated Landsat 9 in March 2015 and it is being built as a near-copy of Landsat 8 for launch in the 2021 timeframe. The SLI program will work closely with industry to support and infuse advanced satellite, scientific instrument, and overall system technologies into future missions. The robust SLI architecture ensures that high-quality Landsat imagery, freely accessible in an open archive, will continue to be available for critical uses such as monitoring the irrigation of farmland in the American West.

NASA's Astrophysics program continues to operate the Hubble, Chandra, Spitzer, Fermi, and Kepler space telescopes, the Stratospheric Observatory for Infrared Astronomy (SOFIA) airborne observatory, and other missions that together comprise an unrivaled resource for the study of our universe. NASA's next strategic Astrophysics mission, the James Webb Space Telescope, continues on schedule for its 2018 launch and remains within budget.

With this year's request, NASA will continue developing the Transiting Exoplanet Survey Satellite (TESS) for launch in 2018. TESS will extend the pioneering exoplanet discoveries of the Kepler Space Telescope by looking for rocky exoplanets orbiting the nearest and brightest stars in the sky in time for Webb to conduct follow-up observations. During FY 2017, NASA will also continue formulation of the Wide-Field Infrared Survey Telescope (WFIRST), the top priority for large-scale missions of the most recent National Academy of Science Decadal Survey in Astronomy and Astrophysics.

With the FY 2017 budget request, NASA will broaden its reach into the Solar System with increasingly capable missions and continue to produce a series of exciting achievements in planetary science. In one of the biggest stories of the past year, NASA's New Horizons spacecraft captured our imaginations by showing us the complexity of one of our most distant and smallest neighbors. And despite being far beyond Pluto now, the intrepid probe continues to send volumes of pictures and other data over a radio link to Earth stretching billions of miles. At the same time, the Juno spacecraft is on its way to Jupiter where it will achieve a first-ever polar orbit of the gas giant this July 4th. And just two short months later, NASA's robotic asteroid rendezvous and sample return mission, dubbed OSIRIS-REx, will launch to the near Earth asteroid, Bennu, where it will collect a sample for return to Earth in 2023. In late 2016, after more than ten years of exploration, the Cassini spacecraft will begin a daring set of orbits called the Grand Finale that is, in some ways, like a whole new mission. The spacecraft will repeatedly climb high above Saturn's poles before probing the water-rich plume of the active geysers on the planet's intriguing moon Enceladus, fly by Titan, and then dive between the planet and its innermost ring 22 times. No other mission has explored this unique region so close to the planet. Moreover, the FY 2017 request supports several other missions operating throughout the Solar System. These include the Curiosity rover at Mars, the Lunar Reconnaissance Orbiter, the Dawn spacecraft currently at Ceres, and the Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiter.

Looking to the future, the FY 2017 request continues development of a new rover that in 2020 will carry seven carefully selected instruments to conduct exceptional science as well as for the first time ever,

cache a Mars sample for a potential later return to Earth. The budget also continues formulation for a mission to Jupiter's moon, Europa, to explore the most likely host of current life beyond Earth. In addition, this year's request releases a new announcement of opportunity for NASA's New Frontiers Program and selects at least one new Discovery mission for development – ensuring this essential path of exploration for the next decade.

NASA's Heliophysics program operates 18 active missions comprising 28 spacecraft, called the Heliophysics System Observatory (HSO), to understand the Sun and its interactions with Earth and the solar system, including space weather. NASA continues to gain important insight from the HSO, including new observations from the Magnetospheric Multiscale (MMS) Mission, which entered full science mode September 1, 2015. The FY 2017 request supports the continued development of the Solar Probe Plus (SPP) mission, planned for launch in 2018. SPP will fly closer to the Sun than any previous mission to study its outer atmosphere. The request will enable the continued development of critical instruments for the NASA-ESA Solar Orbiter Collaboration mission scheduled for launch in 2018. NASA will continue development of the Ionospheric Connection (ICON) and Global-scale Observations of the Limb and Disk (GOLD) missions. ICON will investigate the interaction of solar forces and Earth's weather systems that drive extreme and unpredicted variability. GOLD will measure densities and temperatures in Earth's thermosphere and ionosphere to improve our understanding and potentially our predictive capabilities of activity in this region.

Aeronautics

NASA's Aeronautics program advances U.S. global leadership by developing and transferring key enabling technologies to make aviation safer, more efficient, and more environmentally friendly. With a request of $790.4 million for Aeronautics, NASA will initiate a bold series of experimental aircraft and systems demonstrations as part of the President's 21st Century Clean Transportation Plan. NASA has laid the groundwork for this initiative through years of research at the component level, through computer modeling, ground tests, and flight tests. In partnership with industry and academia, we have developed technologies and designs that have the very real potential to dramatically reduce fuel consumption, harmful emissions, and noise. NASA is ready to take the next step. With the FY 2017 request we will move out on a plan to develop and fly "X-plane" demonstrators. We will demonstrate and validate transformative concepts and technologies as integrated systems in flight to meet the most challenging needs of aviation. NASA will begin the development of a series of ultra-efficient subsonic transport experimental aircraft, and initiate the detailed design and build of the world's first low boom supersonic flight demonstrator.

NASA's request for Aeronautics also increases investment in developing revolutionary tools and technologies to support X-plane developments, enabling further advances for future transformative vehicle concepts, nurturing university leadership in innovation that will also foster and train the future workforce, and leverages non-aerospace technology advancements.

NASA will continue to advance research and development into the next generation air traffic management system to realize the full vision of Next Generation Air Transportation System (NextGen) NASA will complete a series of major flight tests to demonstrate significantly more efficient arrival and departure operations in full partnership with Federal Aviation Administration (FAA) and industry. NASA will also continue to lead the world for enabling safe UAS operations by developing key technologies that will integrate UAS operations in the National Air Space and realize small UAS operations safely at low altitude operations.

In conclusion, the program of exploration we propose to execute with the FY 2017 request is the envy of the world, and should be a source of pride to the Committee, the Congress, and the American people.

With constancy of purpose and consistent support from the Congress, we look forward to extending human presence into deep space, over the course of the next decade.

Mr. Chairman, I would be pleased to respond to your questions and those of other Members of the Subcommittee.

OUTER PLANETS AND OCEAN WORLDS

Mr. CULBERSON. Thank you, General Bolden. We appreciate the fact that the budget does indeed include an Outer Planets and Ocean Worlds exploration program. That is something that these young people in the audience and around the country are going to become increasingly excited about as they discover that there are indeed water worlds out there that have probably some of the best potential for us finding life on another world. And I am very pleased to see that the budget request does acknowledge that. We in the Congress included in the 2016 bill, created an Ocean Worlds program for that reason and have focused on the Europa mission in particular as the first one to fly because of the recommendations of the decadal survey of planetary sciences.

For the young people in the audience and anyone listening, every ten years, General, the scientific community gets together at the National Academies and develop a 10-year plan looking forward to decide what are the most important missions that should be flown in heliophysics and studying the sun, or studying the Earth, and studying the planets, and then looking out beyond our own solar system. And that decadal survey is a good road map for the next 10 years. And in our 2016 bill I made sure we included in our 2016 bill guidance to NASA to look to those decadal surveys in each one of those areas as kind of a blueprint of where NASA should go over the next decade. And that blueprint for the planetary scientists listed the Mars mission 2020 as No. 1, to cache samples from the surface and retrieve them later. That mission has been funded and is going to be done. And their number two priority this decade, and their top priority last decade, was the mission to Europa. Because that moon contains at least two to three times more salt water than there is on Earth, it has all the basic ingredients for life to be present. And so we are very supportive of the work that NASA is doing to send an orbiter and a lander to Europa to find out whether or not there are organic molecules in that ocean. And could you comment, General, on your feelings about the decadal survey recommendation? Do you agree with the decadal survey recommendation that the Europa mission is important?

General BOLDEN. Mr. Chairman I am, having talked to Steve Squyres who chaired the latest planetary decadal, I agree with the priorities that they set. And one of the things that I was most impressed with was the fact that he really looked hard at cost. And so, you know, I think that they are projects that can be done. And that is why we have sent Mars 2020 and a sample return as number one in compliance with the decadal survey and we are now trying to formulate the mission to Europa. And I assume we will talk a little bit more about that as the hearing goes on.

Mr. CULBERSON. Sure. You know, the Congress gives you direction.

EUROPA MISSION

General BOLDEN. Yes, sir.

Mr. CULBERSON. That is actually the one mission it is illegal for NASA not to fly, is the Europa mission, because it is so important that we find out whether or not we are alone in the universe, and

then it will also help I think galvanize the public. One of the reasons I have been so interested in this mission is not only has it been, in the decadal survey it was the top priority last decade and the last NASA administrator, your predecessors neglected it. It was cast by the wayside. And this time we want to make sure it is done. So it is a directive from the Congress to make sure this mission is flown and we made sure you have got the resources to do it. And right now I know that design work is going forward on the lander, correct? And——

General BOLDEN. Mr. Chairman, we have a total effort going on on the Europa mission entirely, which is orbiter and lander. I think you and I have discussed this before. My strong recommendation to the committee and my strong recommendation to the community would be that we separate an orbiter from a lander in order to optimize our chances of being successful with both. When we look at the Mars program as a model, before we landed, we actually landed Mariner 4 in 1965 and it was 11 years later when we put Viking 1 and 2 on the surface of Mars. And that was for a very good reason, the fact that we just did not know the Martian surface and we wanted to make sure that we understood it fully. We are in the same situation with Europa. We want to make sure that we characterize the surface of the moon prior to deciding on a place that we are going to put a lander. We are definitely working on a lander. But, you know, my strong recommendation would be that we separate a lander from an orbiter in the mission. But that remains to be done. We expect that we will be at preliminary design review in 2018. And at that time it will say whether or not we have a lander and an orbiter together, it will say what kind of launch vehicle we use, and the like. So we are responding to the direction from the Congress.

Mr. CULBERSON. Good. Thank you, sir. And I understand what you are saying and appreciate the fact that your scientists are looking at, engineers, right now whether to launch the lander separately and, you know, the orbiter would obviously go first. And I understand what you are saying. The discussions are ongoing right now——

General BOLDEN. Yes, sir.

Mr. CULBERSON [continuing]. About whether or not you want to put the lander on the same rocket or launch it separately. It may indeed be, I think you are probably right, it may be a good idea to launch them on two separate SLS rockets so that the orbiter goes first in order to scout the surface, as Mariner 4 did. Mariner 4 was of course a fly by, and then they did orbiters, and then landed second. So that is the direction the Europa mission is taking. I think that is a very good idea. And as always, your folks at the flight centers do a terrific job.

General BOLDEN. Yes, sir.

FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS

Mr. CULBERSON. I am particularly impressed with the work that the flight centers, for example, the Jet Propulsion Laboratory is a Federally funded research and development center and Johns Hopkins University has a similar arrangement with——

General BOLDEN. APL, Applied Physics Laboratory.

Mr. CULBERSON [continuing]. APL, Applied Physics Lab.

General BOLDEN. Yes, sir.

Mr. CULBERSON. And they do a superb job. And you have the universities that are essentially running the flight center and they are in a five-year contract, I think, with NASA and they are reviewed every five years. I am keenly interested in trying to find a way to replicate that model for some of the other flight centers to get the young people involved, the university communities, scientists, engineers, graduate students involved in helping these NASA flight centers. From your perspective I really would love to have your thoughts, General——

General BOLDEN. You are going to get me in trouble, Mr. Chairman.

Mr. CULBERSON [continuing]. How would, it is difficult with the human space flight program. I think that is very different. That is a real challenge. But when it comes to, for example, Ames in Mr. Honda's district, with all those great universities right there, Stanford and others right here, the Glenn Flight Center in Ohio, could you give us your thoughts on how we could think about looking into the future transitioning perhaps Ames, and to let maybe have Stanford and some of the other great universities in the area bid on adopting Ames, taking over Ames, and running it like a Federally funded research and development center like JPL, like Cal Tech does JPL. How can we replicate that model at some of the other flight centers and what are your thoughts on that?

General BOLDEN. Mr. Chairman, I, you know, the National Academies have done studies on this in the past. We have actually done studies and based on the information that I have, mainly to include information yesterday from my deputy who served on National Academy boards that looked at this, I would not recommend that NASA go the model of, you know, of more than one FFRDC. The examples you gave, Ames does an incredible job right now of engaging the students, both undergraduate, graduate, and post-grad on the campus of Stanford and other neighboring universities. Right now if you go out to the Ames Astrobiology Center you will be introduced to something called the biobrick. And that is the result of collaboration between students at Stanford University and people at the Ames Astrobiology Center. And that is what we are going to use when we go to the surface of Mars. So it is a study that probably needs to be done again. But based on my limited knowledge and what I have read from the Academies and others, I would be leery of trying to assign more than the FFRDC that we have right now for NASA.

Mr. CULBERSON. Why?

General BOLDEN. Well I have served on the advisory committee for Lawrence Livermore Lab. And one of the things that frustrated me was the fact that it did not get along with its sister labs. Each lab is an entity unto its own. They are run by a contractor. There is no single mission. I would really defer to the Secretary of Energy, because he lives and breathes with FFRDCs everyday. That is the bulk of his centers are that way. And I just found, you know, as the NASA administrator when I set a mission for the agency and I bring all the center directors together and say, okay look, I want to hear everybody's opinion, I want to hear all dissenting

opinions, and after that I am going to make a decision. And we are going in that direction. The journey to Mars, for example. You could not do that with a bunch of FFRDCs. Because they operate independently. They do not have any single person like the NASA administrator who says you are going to do this. They are all set up for different things. That would be my, you know, my opinion, my humble opinion.

EARTH SCIENCE PROGRAMS

Mr. HONDA. Thank you, Mr. Chairman, maybe we can continue this discussion. This is the first I have heard of it and it is kind of an interesting question. But it is one that came out of right field for me. So we will talk about that.

General Bolden, as you know I am a strong supporter of NASA's Earth Science program, although not everyone in Congress is of the same view of NASA's Earth Science. Could you please talk about some of the ways in which NASA's Earth Science program benefits American private sector enterprises and the nation as a whole? And what returns are we getting on this investment? And in terms of the Agency's Earth Science portfolio, what role does airborne science play? And in the interest of the recent announcement of the Earth Venture instrument program and the use of CubeSat and SmallSat, what role do you see these two entities playing in earth science?

General BOLDEN. Congressman Honda, when I think about the value of earth science in the way you phrase your question, it has enormous both economic and strategic value. And I will try to give you a couple of examples. For example, we have the GRACE mission right now and SMAP. And I hate using acronyms but I will. I could read you the long name but it will not make any difference. But both of them look at water on the planet. GRACE uses gravity to determine the amount of water in reservoirs and underground aquifers and the like. And then SMAP is actually looking at soil moisture for its primary part. Those have provided useful information to farmers, to decision makers, particularly out in the west right now as they go through droughts. John Deere Corporation is working with us, looking at the potential to use GRACE and SMAP data in some of the work that they do. A lot of farmers today follow a model that was developed in Israel, something that is called drip irrigation. Where satellites feed data down to the ground, it goes into a computer, the computer says, okay, the ground is nice and moist today, do not need to water. Tomorrow the satellite may come over and say, it is really dry, you need some water. And the computer determines how much, and it turns on the drip system and it goes right into the root system of the plants or the vines if it is a vineyard out in southern California, you know, in the valley where most of our wine is done.

UAVSAR, since you mentioned airborne Earth obs, UAVSAR is a series of, it is a synthetic aperture radar that we can put on a number of NASA airplanes. And that has been used, it was used in the Gulf during the BP oil spill years ago. It has now been, we are trying to deploy it at the request of FEMA and the National Weather Service to look at levies and to look at some of the other structures in east Texas and Louisiana resulting in the floods, try-

ing to help decision makers to understand what to do. So all of those things are the use of NASA assets for economic and strategic value. Not to mention Landsat, which we actually build Landsat for USGS, for the U.S. Geological Survey in the Department of the Interior. But it is through that 43-year program now that we have had the most robust land imaging system I think in the world.

NASA AERONAUTICS

Mr. HONDA. OK. Thank you. Very quickly, the aeronautics program, as you know, is the first A in NASA. And it comprises the work that NASA has been doing for a long time now. But given the size of the program relative to other NASA directorates, it does not usually get the same level of public attention as other programs do. I would like to focus some attention on this important work. Can you talk a little bit about some of the ways in which the work of the aeronautics directorate and the funding that you are requesting for it, how can it help enhance our competitiveness in aviation, create jobs here, some of the other benefits that personally I am looking for, too——

General BOLDEN. Well as a former Marine Corps pilot, since I do not fly anymore, I am partial toward the first A, the big A in NASA, which is aeronautics. And I am very proud to say that over the period of time that I have been the NASA administrator we have taken a crawl, walk, run. But thanks to the committee, again, we have funding in the NASA budget. And the President is proposing in the 2017 budget additional funding that will allow us to get into our New Aviation Horizons program, a program that came about as a result of revamping our aeronautics strategic plan in 2014. And in looking with industry and academia at six strategic thrust areas that we want to do in aeronautics.

I think every member of the committee should have a little flyer like this, and I apologize that I do not have one of these for Europa. But we talk about Europa a lot and we do not talk about aeronautics. So that is why I chose to focus on aeronautics and I will hopefully get it to the students back here. But it talks real quickly about the New Aviation Horizons program whereby NASA, for the first time in decades, is actually going to be able to engage in building experimental airplanes again. What we call X-planes, but they are flight demonstrators.

The top ones for us right now, and it is just because industry is so far along on wanting to build a supersonic transport that the first one out of the chute is going to be the low boom supersonic demonstrator that will allow us to give data to the FAA so they can change the regulations that today prohibit supersonic flight over ground. Another one is hybrid electric propulsion. So that will actually save fuel, be much more efficient if you will. We are looking at a hybrid wing body. All of these things will help industry and we think it will help the airline industry, for example, to save as much as $225 billion over the next 25 years as a result of the work that we at NASA have been doing with the aviation industry.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you very much. Mr. Jolly.

LAUNCH COMPLEX 39A

Mr. JOLLY. Thank you, Mr. Chairman. Mr. Administrator, thank you for being here. A couple of quick questions, first one about Kennedy Space Center. A couple of years back NASA moved to move the launch complex 39A over to private vendors, if you will, for I guess the comprehensive suite of management. Can you update us on that? And on the competition for infrastructure if you will? And whether or not that has slowed SLS or not?

General BOLDEN. It has had no effect on SLS whatsoever. And I think the reference you make to 39A is, that is the historic launch pad from which Neil Armstrong and his crew launched. When we phased the Shuttle out we determined that we did not need two full launch complexes. And rather than mothball 39A we made the decision that in our ongoing effort to try to commercialize as much as possible we would compete that. I know there were several companies that competed. SpaceX was finally awarded a long term lease for 39A. I have not physically seen it myself but everybody that tells me says that it has undergone a complete revision and it is incredible. That is where they intend to launch the Falcon Heavy later this year, we hope. In the meantime we have continued our work on SLS and Orion. And I would invite anybody who wants to go to Michoud down in Louisiana, or go to the Cape if you want to see Orion. We actually have, we completed the welds on the first crew module for Orion that will fly on EM–1, an uncrewed flight. But that is done. We are continuing to work on Orion. It is on schedule. SLS, we are actually producing barrel sections that go in the core stage of SLS down at Michoud. We just last week at Stennis fired a full 500-second firing on one of the RS–25 engines that is going to go in the cluster of four for SLS. And we are about to start testing on the engines that will be used for EM–2. We have test fired the SRB, the solid rocket booster for EM–1 out in Utah and we have another test firing coming up this spring. So I do not, you know, our work with commercial entities has actually enhanced our work with SLS and Orion because it has freed us up from having to worry about providing access to low Earth orbit. I know Mr. Kilmer is really interested in commercial space flight and stuff.

Mr. JOLLY. Sure. Sure.

General BOLDEN. It is the partnership between commercial and government that has actually allowed us to focus on SLS, Orion, and deep space exploration while industry and entrepreneurs take over access to low Earth orbit.

Mr. JOLLY. So it has been a success at 39A without any delay in operations?

General BOLDEN. There has been, I would have to ask Elon about whether or not he thinks there has been no delay.

Mr. JOLLY. Sure.

General BOLDEN. As far as I know, we have not delayed him. He is not moving as fast as I think he thought he was, since he had actually said they were going to launch last year. But they are doing very well by all our measures that we can see.

ENHANCED UPPER STAGE

Mr. JOLLY. All right. You mentioned EM–1. On EM–2 in 2021 we provided funding through this committee for enhanced upper stage in last year's bill and it is not in your request I believe?

General BOLDEN. It is not in the 2017 request—however we continue to work on the exploration upper stage as a part of the 2016 appropriations. And because we really want to fly the exploration upper stage as quickly as we can. And we will, as I explained to the chairman, our hope is that we will be able to work with the committees in the final determination. Because as I said again, it is you that decide what the ultimate appropriation is. And so—but we are working on the exploration upper stage, although we did not fund it, because we had to prioritize and we want to keep moving. We are actually looking at, we look at the SLS and Orion as part of a program.

Mr. JOLLY. Sure.

General BOLDEN. Everybody gets stuck on EM–1 and EM–2 and we are busy worrying about this ten-year period of time that we are going to be operating in cislunar space. And we will need multiple vehicles, many more than EM–1 and EM–2. So that is what we are focused on.

Mr. JOLLY. But to achieve the EUS larger capacity for EM–2, there would need to be 2017 funding, right?

General BOLDEN. You know, I——

Mr. JOLLY. I understand it is not in your request. But if there is no funding there in 2017, does that disrupt the ability to then have the EUS in the EM–2 in 2021?

General BOLDEN. Let me go, I will take it for the record. Because I want to give you a thorough answer. It would cause us, as you said, to interrupt the flow of the production of the exploration upper stage. But based on the budget that we submitted, we think we have a way to still produce the exploration upper stage for EM–2, which is what we would like to do.

Mr. JOLLY. EM–2, OK.

General BOLDEN. But we need to work with the committee, the appropriations committees, to make sure that we are getting the funding that would be necessary to do that.

Mr. JOLLY. OK. Thank you. Thank you, Mr. Chairman.

FISCAL YEAR 2016 APPROPRIATIONS DIRECTION

Mr. CULBERSON. Thank you, Mr. Jolly. General Bolden, just if I could very quickly, to be sure that you all are following, NASA is following the appropriations bill.

General BOLDEN. Yes, sir.

Mr. CULBERSON. OK.

General BOLDEN. We are, and that is what I meant, Mr. Chairman. We are working on the 2016 appropriation.

Mr. CULBERSON. You are working, exactly. That is very important. Because over the years that I have had the privilege to serve on this subcommittee, I got so frustrated with predecessors, the previous President, not just this President but previous Presidents, who did not give NASA the attention that you deserve, the support that you deserve. The President would come out with a budget and

NASA and every other agency would just change direction and start following the budget request instead of the appropriations bill. And I got so frustrated with it. Because it is damaging to the exploration upper stage, to these incredibly expensive and complicated spacecraft and rocket programs for the agency, all these fine men and women who have devoted their lives to building these rockets and spacecraft, to change course and start following the President's budget.

This is a very important point I just want to drive home, is that the—I am pleased to hear you say you are following the appropriations bill. Because I put statutory language in last year's bill and this one that says literally no agency can change any program, policy, you cannot change funding levels for any program or policy based on the President's budget. You have to follow the appropriations bill. And you are following the appropriations bill?

General BOLDEN. We are following the 2016 appropriations presently, sir.

Mr. CULBERSON. Thank you. So the budget recommendation for the President is simply a recommendation for our discussion. As long as you follow the appropriations bill, we are good.

Mr. HONDA. Well that is the law.

Mr. CULBERSON. That is the law. Right. But it is so frustrating to see the agency change course——

Mr. HONDA. Yes.

Mr. CULBERSON [continuing]. When we love you, we are devoted to you, and we want you to stay the course and follow the 2016 appropriations bill. Thank you. Mr. Kilmer.

NEW SPACE COMPANIES

Mr. KILMER. Thank you, Chairman. I was just observing, it is nice to have an agency come in where they are told they are loved. So congratulations.

General BOLDEN. I am all in.

Mr. KILMER. So thanks for being with us. You correctly observed my zeal for some of the exciting work being done by innovative entrepreneurial companies, a lot in my neck of the woods which is getting a reputation as sort of the Silicon Valley of space. But my interest goes beyond the parochial. It is excitement about the work that is being done, from building rockets and launching satellites, to Earth imaging and remote sensing, to even some further out there ideas, including mining of asteroids and sending tourists to space. You know, I think there is a lot of innovation and technical development that is happening and it can lead to a lot of good American jobs. I guess—and not to mention the fact that it can bring down some of the costs associated with NASA's mission.

I guess I just want to get a sense from you of how should NASA leverage these new space companies, both to encourage growth of the industry but also to maximize the bang for the buck for what NASA spends on exploration and discovery in space? And also if you can give a sense of do you have the direction and the authority and the resources you need for those kinds of partnerships with the private industry?

General BOLDEN. Mr. Kilmer, you know, thanks to this committee and the Congress and the appropriations funding in 2016,

the one area where we were lacking was Commercial Crew. And thanks to the appropriations in 2016 we are now stepping it up and catching up. And both of our providers, Boeing and SpaceX, are telling us that they will be ready for their certification next year, 2017.

In a case that is close to home to you, what our process allows us to do in working with industry and academia is it is not one size fits all. So we have the ability to use Space Act Agreements which are a form of contract; it is other transactional authority. It is not a real hard contract, where they have to follow FAR, the Federal acquisition regulation. Blue Origin, for example, they are where they are today in the development of the BE–4 and the BE–3 engines that are probably going to enable us to free ourselves from the RD–180; they are three years down the road because of the work that they did with us through a Space Act Agreement at Stennis in testing components of those engines. They did not test the whole engine because they do not need to. They have got their own test facility. The same thing with SpaceX, Orbital, you look at companies, some enter into contracts with us and others just want to do a little bit. So I think that is the way we have leveraged the ability of the, you know, the commercial providers.

As I mentioned to Mr. Jolly in his question, it has freed NASA up to do exploration. To do the big things that governments have to do. You know, a lot of stuff we do you cannot expect a private company, even with a billionaire leader, to accept the risk for some of the what seems to be crazy stuff we do every once in a while. It is only a government organization that should do that.

NEW TECHNOLOGIES FOR FUTURE SPACE MISSIONS

Mr. KILMER. I want to focus some attention on sort of a specific issue with regard to new technologies and some of the work being done by private industry. It is undoubtedly expensive to send supplies and equipment into orbit, it is also not easy, let alone sending those supplies all the way to Mars. And you have seen companies develop ways to do everything from mining minerals and other resources such as water from asteroids and incorporate 3D printing technologies into space systems so that large bulky components can actually get manufactured in space instead of trying to fit those pieces into rockets. Which I think is amazing and innovative and out of the box. So how does and how should NASA partner with these innovative companies to incorporate these new technologies into planning for future space missions? You know, and is NASA working with industry partners to develop these new technologies, for example solar electric propulsion to transport cargo and equipment beyond Earth orbit?

General BOLDEN. We are. And another example I will give you is for the mission to Mars. The solar electric propulsion powered vehicle that is going to carry cargo. Or for our Asteroid Redirect Mission. That is going to be a robotic vehicle that is going to go to the asteroid to get a big boulder. We are not developing game changing solar cells because we are partnering with industry. There are a few companies, and I will not bother to name them, but most are out in Southern California, others are different places, who are doing game changing solar cells. Our job is to try to figure

out how to package that. How to put a giant solar array that is using this high energy solar cell, how do we package it and put it into the nose cone of a spacecraft? So that is they way we are leveraging, letting them do the development of the game changing technology that way. And our job is to fit it into a spacecraft.

If I go back to Blue Origin again, they are using 3D printing to produce engine parts. SpaceX is using 3D printing to produce engine parts. We are using 3D printing on the International Space Station now to produce tools. They are prototype. They are not metal tools yet because we have not figured out how to do metal in the microgravity environment of space yet because we still have to feed ribbons. We have got to figure out a way to contain powders that you would do if you are going to do something like inconel or stainless steel. But we are working with industry hand in glove. And I think if you go into some of our laboratories, or we would like to see it in some of their factories but we do not do it yet, you will see them side by side with us in trying to get to the places we want to go.

Mr. KILMER. Terrific. Thank you. Thank you, chairman.

Mr. CULBERSON. Mr. Palazzo.

NASA'S MISSIONS

Mr. PALAZZO. Thank you, Mr. Chairman. General, it is great to see you again.

General BOLDEN. Good to see you, Marine.

Mr. PALAZZO. You tried to get rid of me but you could not. I just went from one committee to the other.

General BOLDEN. Sure.

Mr. PALAZZO. I just wish we could have gotten the 2015 authorization taken care of. But——

General BOLDEN. That would have been nice.

Mr. PALAZZO. We did. The House did its business. The Senate, of course, was absent. We will just leave it at that. But anyway, it has been a great pleasure working with you to help NASA create a roadmap and rein in their focus so that we could pursue the mission to Mars and direct our resources and our energies towards that. As you shared with my previous committee and with this committee, that, you know, maintaining America's leadership in space is a priority of yours as it is ours and the chairman's. And we all look forward to the day where we are launching American astronauts on American rockets from American soil. And so we are excited. And you referenced the students in here. I think they are going to be very excited just following the mission for us to get there.

But I would like to start off with a question and it is in regard to—well, let us just say you know NASA is the only Federal agency tasked with space exploration. Is there any other Federal agency tasked with that mission in its charter?

General BOLDEN. Human space exploration, none. DOD does a little bit of space exploration and——

Mr. PALAZZO. For other purposes.

General BOLDEN [continuing]. For other purposes.

Mr. PALAZZO. Right, civilian purposes.

General BOLDEN. We are the primary, we are the civil, the only civil agency tasked with space exploration.

Mr. PALAZZO. And of course it is important that we focus on commercial crew and cargos. You have testified today and previously that it frees NASA up to focus on the exciting stuff of deep space exploration. And I understand that. But yet every time we look at a budget I see the earth sciences budget increasing and I see the space exploration budget decreasing for NASA. And of course it is Congress that comes in and helps plus up the space exploration budget. So when there are 13 other Federal agencies tasked with climate science, do you think it is the best use of NASA's money to put into earth sciences? Or would it be better to focus on, you know, commercial crew, cargo, and deep space exploration?

General BOLDEN. Mr. Palazzo, one of our charges in the original NASA Space Act of 1958 is to take care of the Earth. And so it has always been a responsibility of ours to provide cutting edge technology that can be used by other agencies. We do not do weather. You know, we do not do global warming. We just do data. And as I mentioned before, for 43 years we have produced every successful Landsat satellite that has been used by the U.S. Geological Survey. We produce the satellite, check it out, and give it to them. And then we do not do anything after that. So it is our responsibility to the taxpayer to provide that type of cutting edge technology that can answer some of the questions about our changing climate for them.

I do not think it detracts from our ability to explore at all. In fact, it enhances our ability to explore because, you know, the chairman can teach me on this. He knows a lot more about it than I do. We believe we all started from one thing at the time of the big bang. And you know, we want to understand what is happening to Mars. We want to understand what is happening to other planets so that we understand our own planet better. But we do have to understand what I consider to be the most important planet in the world, which is Earth. And that is what NASA does, is——

Mr. PALAZZO. And I appreciate that. And that is why, you know, focusing on Mars and other planets would be planetary sciences and not Earth sciences. And I understand, but you know, 13 other Federal agencies are spending billions and billions of dollars. I just wish we could take——

General BOLDEN. They do not do it as well as we do.

Mr. PALAZZO. Well, yes. And I wish we would just take the billions of dollars that we spend on it and put it into deep space exploration.

My next question would be, and then this is just out of curiosity, are there any, are you aware of any nation state that has any possible lunar ambitions, whether going there, I know China recently sent a rover. But are they looking to build any type of capacity possibly on the Moon?

General BOLDEN. We are hopeful that a number of our partners, our international partners, are hopeful of putting things and people on the surface of the Moon. We are going to spend ten years in cislunar space, operating in the vicinity of the Moon, beginning in 2018 when we launch SLS and Orion. That will be the beginning of, we have this phrase, we call it the Proving Ground. And a lot

of people do not like it. But it says very simply we are going to spend the decade of the twenties with humans back in cislunar space. We are not ready to go to Mars yet. And so our hope is that over the period of time we will be able to collaborate with some of our international partners to get them to share the load of getting humans back to the surface of the Moon. Others talk about wanting to do a lander. The European Space Agency talks about a Moon village. It is a concept, but it is a great concept when you talk about it. But we have to lead. And leading does not mean we have to do everything. We have to encourage them, support them, so that they can do it. So there are any number of other nations that have a strong interest in going and doing research on the Moon.

Mr. PALAZZO. Right. And I hope those nations are friendly to America.

General BOLDEN. They are all very friendly.

Mr. PALAZZO. The ones we are talking about, right.

General BOLDEN. The ones we are talking about.

SPACE DEBRIS

Mr. PALAZZO. The ones we are not talking about, I am not so sure.

In 2007 a certain nation state decided out of their infinite wisdom they were going to blow up a satellite in space creating a lot of space debris. I think at last count we try to track 500,000 pieces of space debris that orbit our Earth. How does that affect space travel and how does it affect the assets that are so critical to our day to day lives, the quality of our life, our military, our communications, our banking, our financial, healthcare?

General BOLDEN. Congressman Palazzo, just like——

Mr. PALAZZO. What are we doing about it?

General BOLDEN. China, you are talking about the ASAT test that China did. While that was intentional, you know, we had two satellites, two commercial satellites that ran into each other and created the same kind of debris that that did. Anything where two bodies come together in space and collide, whether it is intentional or otherwise, is bad for low Earth orbit. We are trying to work with a number of our international partners on what we call mitigation of orbital debris. That means that when we build a satellite it has to have enough fuel that it will not orbit after it is finished with its lifetime. It will not just stay down there in low Earth orbit and become a target for something. It will either be purposefully deorbited into the ocean and destruct or we will move it into a higher orbit where it will stay for hundreds of years and be out of the way of everybody.

What we are not working on, because DOD, the intelligence agency, NASA, all understand the critical need for coming up with a means to do orbital debris removal. No one today has an active program in orbital debris removal, although some of our international partners would like to do that. That is what they want to focus on. So we have got to do more.

Mr. PALAZZO. Could you real quickly just emphasize the dangers that space debris provides to our Space Station, our space travel, and other very expensive assets in space?

General BOLDEN. A fleck of paint coming at the right angle toward the International Space Station would be disastrous. That is how, you know, it is a big space so I do not want to panic anybody. The U.S. Air Force out in Colorado Springs, along with us, we track as much as we, we track thousands of particles, pieces of orbital debris. And so every once in a while we have to maneuver the International Space Station in order to avoid that. You are right.

Mr. PALAZZO. Thank you, Mr. Chairman. Thank you, Administrator.

NASA INTERNATIONAL PARTNERS

Mr. CULBERSON. General Bolden, real quickly, when you mention international partners, what countries are you thinking about, present and future international partners?

General BOLDEN. We have about 15 partners on the International Space Station today. If you are talking about aeronautics we have 26 partners in something called the International Federation of Aeronautics Research. And so there are a lot; we have more than 800 signed agreements today with more than 120 nations in the world. So NASA is the world leader when it comes to aeronautics, science, and exploration.

Mr. CULBERSON. I just want to be sure we are not talking about the Chinese.

General BOLDEN. Mr. Chairman, whenever we do anything with the Chinese, as I think you and the committee are aware, we submit a certification to you and to the Senate Appropriations Committee listing every individual that is going to be in the meeting, what the subject is going to be. We go through an enormous database——

Mr. CULBERSON. Right, and we clear that with the FBI.

General BOLDEN. We clear——

Mr. CULBERSON. We want to keep that contact very, very limited.

General BOLDEN. I just did not want to mislead anyone that——

Mr. CULBERSON. Because they are not our friend.

General BOLDEN [continuing]. Yes, sir, that we do not do anything with the Chinese. When we do, though, we certify as required by law that the folks that we are working with are not engaged in human rights violations, are not engaged in terrorism, and there is going to be no exchange of technology.

Mr. CULBERSON. Thank you very much.

General BOLDEN. And we have lived by that.

Mr. FATTAH. Mr. Administrator, it is good to see you.

General BOLDEN. Great to see you, sir.

How is Overbrook?

NASA RECRUITMENT

Mr. FATTAH. Overbrook High is doing very, very well, mainly because of your visit. You know, the science program is much more aggressive, but it is the alma mater of Guion Bluford, and NASA holds a special place. Not just there, but there was a time when over 3,000 engineers worked right at GE Re-entry right there in West Philadelphia.

So, let me just first of all thank you for your leadership. It has been extraordinary. We have worked together on a lot of things,

but particularly I am pleased to see the commercial crew and cargo program going well and I appreciate your comments earlier that this worked and working with the private sector, you have a Philadelphia firm that is working with NASA now on new space uniforms for your astronauts. That this commercial partnership is critical and NASA being able to focus in on the things that we cannot do in the private sector and there is not a profit center for as of yet.

I have spent some time, as the chairman is aware, you know, making sure we understand this. So, I was at the Jet Propulsion Laboratory on my last visit. I had my wife with me and we had a great time learning about the great work that is being done, and particularly, looking at some of their science stuff and some of the other work that they are doing.

You talked about the Space Act Agreement. I want to thank you for the partnership with the Boys and Girls Club of America. I am meeting with them later on today. And this worked, and the 4,000 centers—clubs around the country, getting our young people interested in space and science is critically important and we have quite a partnership now of FIRST Robotics, because at some point we have to understand, you know, the Europeans and the Russians just in the last few days, have launched a non-manned mission to Mars, right; looking at methane and looking at some of the questions about life or the potential for life.

And NASA is the premier leader in the world because of the team you have and we have to be able to replenish that team, and so we need young people who are going to focus on this. I have talked to the chairman about this and it is very, very important that we not miss the boat in terms of the critical skill shortage that is going to materialize even more so at our national labs, at NASA, at—you know, in terms of our nuclear enterprise. These are areas—we do not have to worry about the Chinese. We can only have American citizens do this work. The problem is we do not have enough of them in the pipeline that are going to be in a position to do this work, so the last thing we want to do is have made all these investments and then to fall short on the baton pass to the next generation of leaders. So it is very, very important.

I want to thank you for the leadership that you have put in. You know, we talk about the, you know, the rocket ships and all this, but your presence at a school like Overbrook, your presence talking to young people—and your team, I came over and met—witnessed your manager's meeting, in which you place in every single part of the agency, a premium on making sure that they are working to get people ready to take on the work and the leadership at NASA.

I wish you would just take a few minutes and talk about this part of your mission.

General BOLDEN. One of the things that I think everybody knows is we have been the best place to work in the Federal government in the large-agency category for the last four years and it primarily comes, I think, because of our mid-level managers and leaders, and it is the way that we push employee engagement, making sure that, one, they emphasize the critical importance of diversity, which means numbers, but that in itself is not as important as inclusion. If there is a woman in the room, or there is a minority in

the room and nobody let's them say anything, they may as well not even be there. So inclusion becomes the most important part of the D and I that we do. We put a lot of emphasis on it. We have a D and I partnership, that is all the leadership of the agency and we come together several times a year to talk about how we promote diversity and inclusion in the agency.

And I think, you know, we try to pass that on when we go out and—every time I talk to young people I try to explain to them that, you know, they got to get used to being in a room where everybody doesn't look like them, because that is the world and they have got to be able to sit in a room where everybody doesn't think like them and they have got to be able to give them the respect of at least——

Mr. FATTAH. I thought the chairman and I were like kissing cousins or something. I mean we look almost identical, right?

General BOLDEN. Well—but that is sort of it. Employee engagement, I think, is the key for—people that ask about secret sauce. There is no secret sauce; it is our mid-level leaders who actually are the ones who touch and feel our employees every single day and try to impress them.

Mr. FATTAH. Well, thank you and thank you for your extraordinary career in public service.

Thank you, Mr. Chairman.

Mr. CULBERSON. Ms. Roby.

EM–1 AND EM–2 LAUNCH DATES

Mrs. ROBY. Thank you, Mr. Chairman, and thank you, Administrator Bolden, for being here. Thanks for being in front of our committee and all you do to advance our nation's future in space.

I am also glad that you and NASA officials, earlier this year, announced Todd May the official director of Marshall Space Flight Center in Alabama. Marshall plays a major role in NASA, as you know, and has a great impact on my home state. It employees almost 6,000 civil service and contractor employees with an estimated $3.8 billion in economic output and $96 million in state and local tax revenues.

Just last week, NASA Day was held in my hometown of Montgomery where Todd May and his team from Marshall spread the word about the importance of Alabama's role in NASA—with NASA.

NASA's Journey to Mars runs through Alabama, are the words that Director May—and I could not agree more—those are the words that he used, and so with that, I want to touch on Space Launch System and the Orion spacecraft. I know you talked to Mr. Jolly a little bit about this; there are suppliers in all 50 states that contribute to SLS and that shows a national effort to deep-space exploration.

And in the fiscal year 2016, NASA asked for $1.3 billion for SLS, and Congress, led by this subcommittee, made it to $2 billion, which was enacted into law. And this year, the president's request calls for $1.31 billion, and so, wouldn't you guess that Congress, again led by our fearless chairman here, this subcommittee would get funding upwards of $2.8 billion for this fiscal year. That is what we need, and I want to ask you to contribute to the conversa-

tion that your agency does project when we will reach EM–1 in 2018.

But the question is, do you actually think that we can meet this launch date with the funding request of the President, rather than what we hope to achieve here on this subcommittee?

General BOLDEN. Yes, ma'am. There is no doubt in my mind that we will fly EM–1 in 2018; that is what the President's budget supported and that is how we picked it.

And, in fact, going back to something that Mr. Jolly said, and I should correct one thing, 2023 is the Agency's commitment date to EM–2, and that is based on the President's budget run out. That is not based on appropriations. So, 2021 is a date that we said, you know, we would hope to launch, if instead of the run out that comes from the President's budget, we got——

Mrs. ROBY. Well, do you think that is likely to occur at the trajectory of the President's budget request?

General BOLDEN. The President's budget, we will launch in 2023 and that is——

Mrs. ROBY. Oh, I was asking about 2021. If Congress were to increase the funding to the levels that——

General BOLDEN. I don't, you know, I try not to get into conjecture. If Congress increases the budget, we will use it to buy down risks. We will go out and procure advanced parts that we will need for later on in the program.

The discussion we had a little bit earlier was that we are actually looking at supporting a program and not just the first two flights. So, if we got more money, we may actually go out and get long lead items that would have no effect whatsoever on EM–1 or EM–2.

What I cannot do is bring EM–2 forward, put all the money into that, have no long lead items and have no program. So, it is—I trust my—people like Todd May and his team to tell me what they need and when they need it.

What would really help is even appropriations, not—it is important to have magnitude, but it is also—it is invaluable, for those of you who have been in business, to be able to follow a funding curve that lets you have a development program. We have never done that. NASA's funding curve has always been a flat line; that is not a development program. And we have people like Todd and his team that take a flat, non-development program curve and make it work.

So, I am saying a lot to say that 2023 is the date to which we committed and we will make that date on the President's submission for 2017. If we get more money, we will buy down risks. We will do long lead items, and we believe that would enable us to launch sometime earlier, but I don't—you know, I will let Bill Gerstenmaier and his team come back and talk about what those specific dates are.

Mrs. ROBY. OK. Thank you.

I yield back.

Mr. CULBERSON. To follow-up on Ms. Roby's question, she is correct; we are, all of us, strong supporters of getting the SLS Program up and running as quickly as possible, but you said you are

doing a run out? Your estimates on when you could launch are based on the President's budget?

General BOLDEN. We look at——

Mr. CULBERSON. You really cannot use that; that is just simply a recommendation. What matters is the appropriations.

General BOLDEN. You are absolutely right. The spending this year is determined by the appropriations we get. You know, in my world, then I have to pick and choose some amount of funding, and so I pick what we assume the run out on our budget is going to be—it will get us to 2030; that is impossible to think that——

Mr. CULBERSON. Based on the President's recommendation?

General BOLDEN. Based on the President's out year budget, yes.

But we state—Mr. Chairman, we state that very clearly, that based on the President's budget request at our key decision point where we made our official announcement about the date for launch and the cost for the vehicle, that very clearly states that that is based on the President's budget request, not on a single year's appropriation. And we also, as I just said to Mr. Jolly and Mrs. Roby, if the Congress chooses to fund us at a higher level, that conceivably draws the launch date in, but not necessarily.

It depends on—because we are talking about a program, you know, and we want to purchase long lead items. We want to do EUS.

Mr. CULBERSON. Well, it is hard to be critical of this good man because he is a Marine and a good soldier.

General BOLDEN. No, Mr. Chairman. That is——

Mr. CULBERSON. No, but you are following the President—I understand you are—you know, you have to follow what the President's recommended, but I just want to make sure——

General BOLDEN. Yes.

Mr. CULBERSON. Ms. Roby's right; we are going to get you the funding that you need to make sure that SLS is taken care of. You can launch then on—you are expecting that you will be able to launch in 2018 for EM——

General BOLDEN. 2018 for EM–1 and 2023 for EM–2.

Mr. Chairman, you know, you have to understand when we put a lot of these budgets together, we were under sequester. We are still under sequester. That is not done yet. You know, it would be nice for me to pretend that the Congress has solved the sequester question. So, the President's 2017 budget is optimistic, if you compared that with what we would get under sequester. So, I am taking an optimistic view at being able to develop a program. We need to get our financial house in order. I agree with you.

NASA PROGRAM STABILITY

Mr. CULBERSON. Sure. Talk to us a little bit about stability and certainty and predictability. What would be some of the things that, for example, the NASA authorization bill, that Mr. Palazzo mentioned from his work on the Science Committee. I have been keenly interested in this and Chairman Smith has been very supportive of legislation that my predecessor, Frank Wolf, and I developed to try to give NASA a greater certainty and predictability and stability in your out years——

General BOLDEN. Yes.

Mr. CULBERSON [continuing]. So you could plan for the future.

What are some of the things—for example, multiyear procurement, I understand you already have the ability to do multiyear procurement. And what could the—what can you do and what can the Congress do to support you in that effort to give the agency greater stability from year to year, so you are not doing——

General BOLDEN. You really want my answer, sir?

Mr. CULBERSON. I do, thank you.

General BOLDEN. If the Congress were to do one single thing that would dramatically increase the stability that this agency and every other agency of the Federal government, it would be multiyear funding. You know, one-year budgets, they don't—they make life miserable for American industry, for our workers, for everybody. If the Congress—if the Authorization Committee wanted to do one thing, just one thing that would dramatically change the way that this country operates and competes, it would be one-year funding.

Mr. CULBERSON. And you, of course, already have the authority to do multiyear procurement, however, on the big rocket systems and spacecraft.

General BOLDEN. Well, you know, we get two-year money and we get that kind of money. That is not the same as multiyear funding, where instead of giving me a one-year budget, you give me a budget for five years.

Mr. HONDA. You asked him the question, Mr. Chairman.

General BOLDEN. You are not about to do that because——

Mr. CULBERSON. But I want to find out within the existing boundaries of law——

General BOLDEN. Ms. Roby is smiling at me because she won't argue with the chairman.

Mr. CULBERSON [continuing]. Until we have a new authorization.

Mr. HONDA. We know what the law is, Mr. Chairman. The law and the process is: The President proposes and we dispose——

Mr. CULBERSON. Sure.

Mr. HONDA [continuing]. And that is the law.

Mr. CULBERSON. But I mean in terms of multiyear procurement. I am talking about greater stability for the future——

Mr. HONDA. Mr. Chairman, that is the——

General BOLDEN. That was my one—you asked me for one thing that the Congress—that the Authorization Committee could do. The Authorization Committee—should I be quiet?

Mr. CULBERSON. Yes.

General BOLDEN. No. You asked me about authorizers.

Mr. CULBERSON. Sure. Sure. Yes. Yes.

General BOLDEN. Because, as I understand it, the way this thing works is, in a perfect world, the authorizers give you guidance. They give you a roadmap and then you fund it. That almost never works.

You know I have been a NASA administrator for six years. I think I have had two authorization bills, maybe three.

Mr. CULBERSON. Yes, it has been very frustrating, because the House, as Mr. Palazzo says, we do our part——

General BOLDEN. I share your frustration, Mr. Chairman.

Mr. CULBERSON [continuing]. But they disappear in the Senate.

General BOLDEN. Yes, sir.

Mr. CULBERSON. So that—but you would be able to, as you mentioned, do advanced procurement of critical components.

General BOLDEN. Yes, sir.

Mr. CULBERSON. If you already got that authority——

General BOLDEN. That would be incredible.

Mr. CULBERSON [continuing]. If we gave you the funding necessary, for example, on SLS, as you said to Ms. Roby, you could do advancement procurement of critical core components. That is done in the Virginia-class nuclear submarine program, for example.

General BOLDEN. Yes, sir.

Mr. CULBERSON. The Navy will buy components of the nuclear reactors in advance——

General BOLDEN. Yes.

Mr. CULBERSON [continuing]. In order to help make sure that they have got some stability over multiple years.

Let me ask very quickly, when, this year, will you— before I pass it to Mr. Honda—to follow up, one last question on the Europa mission, when over the next few months will you be announcing an announcement of opportunity for the science instruments to be included on the lander for Europa?

General BOLDEN. Mr. Chairman, that is—that won't happen this year. You know, we have to decide, first of all—I think I mentioned earlier that I—and I will—let me take it for the record, because I do not want to misspeak, because I know you have information from JPL and others and I do not want to get cross-wise with the guys that work for me.

Mr. CULBERSON. Take that for the record. Let's do that for the record.

General BOLDEN. Yes, sir.

Mr. CULBERSON. Mr. Honda.

EUROPA MISSIONS

Mr. HONDA. Well, thank you, Mr. Chairman.

I want to go back a little bit on my questions on—that deals with Europa and the astrobiology missions in our solar system. Two weeks ago we had the pleasure, through Chairman Culberson's leadership, of hosting a very interesting hearing on exploring the water worlds of our outer solar system. It started with the Jovian moon of Europa. I am also very pleased that the Science Mission Director had recently recognized other water worlds, including Enceladus, with potentially interesting astrobiology, and opened a New Frontiers competition to look into exploring these worlds, as well.

As part of the discussion with Dr. Elachi and Dr. Lunine, we heard that signs of life and searching for planetary habitability—see, I can say that word today; I fell over that word last time—for life are two different things. We heard that a planned orbiter and potential lander will analyze habitability of Europa, which is quite different from detecting life or signs of life.

So, does life impact your—is searching for signs of life a goal of the Europa orbiter mission and what would be required to actually search for life and not just for habitability, but with the orbiter?

General BOLDEN. This is out of my league, but as I understand it, when we search for signs of life, like the James Webb Space Telescope will help us do, in a lot of the exoplanets and planets orbiting other suns in other solar systems in other galaxies, we are looking for the basic constituents of life, something that could produce microbes, oxygen, hydrogen, potassium. We can do that remotely, but when you are searching for life, itself, there is nothing like, as the chairman says, putting a lander down there and having them go out and touch and feel and get a sample. And is that really a microbe or is that just a disparate collection of the components of microbial life?

So, when people ask me all the time, why don't we just do robotic exploration? Robotic exploration is great, but at some point, you need to put a human into the environment so that we can determine whether we are looking at disparate pieces of life or whether we are actually looking at life, itself.

Mr. HONDA. Does that have to do with—I guess what I heard your term was——

General BOLDEN. And the disclaimer I made, Mr. Honda, was I do not know what I am talking about. You know, I am telling you what my chief scientists and others tell me.

Mr. HONDA. Being a science teacher, though—because a lot of times it is better for me to learn how to ask a question and not know the answer.

General BOLDEN. Yes, sir.

Mr. HONDA. But this whole term handedness of amino acids, is that part of the effort to look at, perhaps other kinds of missions or concepts for the—to get engaged in?

General BOLDEN. You talked about earlier, you and Mr. Kilmer, talked about CubeSats, MicroSats and the like, concepts for the future. When you talk about both, looking for signs of life in and evidence of life are, for example, on future missions to Europa or Enceladus or some of these other moons that have the geysers, the geyser activity, is to fly, you know, a SmallSat or a CubeSat through a geyser where it gets wet. That will tell you whether there is life there.

And, you know, when we talk about future Europa missions, that is what you would hope you will do. You get the guys out of JPL started and they can tell you all kinds of stuff, but it doesn't happen overnight, the way that they sometimes would like to have us believe. It is a slow——

Mr. HONDA. A lot of discussions around that and when we did talk about geysers, it was clear that there were natural-occurring geysers and then there is a—we can impose or create geysers through impacts. Is that something that——

General BOLDEN. I will have to take that for the record, Mr. Honda.

Mr. HONDA. OK.

General BOLDEN. You know, one of the reasons we want to do a very serious study of Europa, for example, with orbiters is because we believe it will take us two years to completely map the surface. You know, you don't do one orbit and you are happy; it is probably two years.

Mr. HONDA. Sure.

General BOLDEN. And that way, we will be able to find out where is the ice thickest? Where is it thinnest? Where is it most like will to—if you are going to artificially try to produce an opening for water to come up, where is it most likely able to do that?

Mr. HONDA. Yes.

General BOLDEN. The other thing about Europa that is, at least I think I understand this, is that some other moons, some of the other icy moons have geysers with regularity, that are predictable. So, you know, you can schedule when you are going to fly through that. And we haven't had—to my knowledge, we haven't had that benefit from Europa yet. You know, we see them sometimes, but we don't—they don't occur with regularity like Old Faithful out in Yellowstone. Is that where Old Faithful is?

TECHNOLOGY TRANSFER

Mr. HONDA. Well, and another way of looking at future funding and how we could look at robust funding and take advantage of the kinds of things that we develop at NASA, the term technology transfer is something that is very important——

General BOLDEN. Yes.

Mr. HONDA [continuing]. In terms of what we do, and as in how this could be—this technology transfer could be commercialized into the commercial arena. So, you know, taking these kinds of technologies and transferring them can provide a lot of jobs and a lot of activities, sometimes beyond what we really would be able to imagine.

Can you talk a little bit about the Technology Transfer Program and explain to me the funding levels that have occurred over time; will this decline or remain the same? It appears that it is declining, and it seems like this is something that we really should be paying attention to, to make sure that we really do, plus-up with the kinds of investments we make in research and development at NASA.

General BOLDEN. I will take it for the record to get you specific numbers, but I seem to recall that when you look at what we are doing now to measure our effectiveness in technology transfer, for example, the Office of Chief Technologist and the science technology—the Space Technology Mission Directorate, between the two of them, we now have a technology transfer database so that we can go in and we can see which technologies have made it to the—into industry or academia or into entrepreneurs.

One of the global ideas about the success of technology transfer is our Spinoffs books that we produce every year, that lists thousands of technologies that have been spun off from work that NASA has done, but that is not a sufficient way to be able to track, to give you metrics on your technology transfer. So, the fact that we have produced this database and that we now keep it better than we ever did before leads me to believe that we are putting more money into technology transfer. But I will get you the data. I will take that for the record.

Mr. HONDA. This will be the last part of this question round. It seems to me the kind of wealth that we can realize from technology transfer should be something that we should track because it gives us a sense in the future that the investment we are making now

will pay off in the long run; not only for the projects that we are planning for, but for the general economy of our country.

And if that pencils out the way I think it should, there should be more attention being paid, as the chairman would like to see, on the kinds of things that we do. It enhances our life. It enhances the quality of your life and it probably provides a lot of different kinds of aspects that we haven't even thought of, and it takes Moore's Law a little further out.

Thank you, Mr. Chairman—oh, Mr. Chairman, I just wanted to give you this. It is something that reminds me of my visit to NASA.

Mr. CULBERSON. I recognize that, right?

Mr. HONDA. I think it sits on one of the things that we are looking at.

Mr. CULBERSON. Well, no; that is the Johnson Space Center. Thank you. Thank you, Mike.

Mr. JOLLY. Thank you, Mr. Chairman.

Just one very quick top-line question. One of the justifications for moving to commercial providers for crew and cargo to station was to essentially spendless or achieve certain efficiencies and savings, so that then you could focus on other activities. Are we spending less? Have we achieved savings?

General BOLDEN. I would say we are, sir. I can, you know, I will take it for the record to get you the specific data on comparative costs between what NASA was paying in the days of the space shuttle program when we had to provide all the infrastructure and everything.

Mr. JOLLY. OK.

General BOLDEN. Yes.

Mr. JOLLY. That is it. Easy question.

Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you.

Mr. Palazzo.

INFORMATION TECHNOLOGY SECURITY

Mr. PALAZZO. Thank you, Mr. Chairman.

From previous hearings in the authorizing committee, there was some focus on the safety and security of our proprietary information. It seems like laptops were sneaking out of the building, personnel, foreign nationals were carrying information out. And it was addressed, of course. We tried to look into, you know, whether those responsible were actually punished and I won't go into that, you know, hopefully they were. But it seemed to be that if the security managers or if the managers of the facilities are not taking the security seriously, because you scientists want to go do scientific stuff, so it comes down to the managers in HR and I guess others to, you know, actually make sure they are taking this kind of stuff seriously.

Because we worked very hard coming up with this proprietary information and we spend a lot of money to do it and it helps America maintain its competitive edge, the last thing we want it to do is walk out the door. Because, again, we know some nation states out there that just love for us to spend all our money, do all the hard work, and they just want to steal what we come up with to help them then take jobs away from America.

How has the culture changed and have you seen this all the way down to the Center level where our managers are taking this seriously? And, if they are not, why are they still managing these facilities?

General BOLDEN. Mr. Palazzo, I think, you know, as I said, everything is a long slog. Since when you were on the authorization committee, you may remember that as a result of several incidents we brought in NAPA to do a study on our Foreign National Access Management Program. They gave us 27 recommendations to date, we have closed 22 of those recommendations.

We also got audits from the GAO and the IG, and we have worked on those. We now have a full-fledged Foreign National Access Management Program where the program manager stood up.

NAPA has just finished a revisit, they have come back and done an update visit on our program, and we are working right now with them on their draft to make sure that we understand what the recommendations are going to be. But the preliminary indication is that we will get a good grade, that they are satisfied with the success that we have done in incorporating this.

We have emphasized export control, we have emphasized the need to follow ITAR. We have now an export control manual that is accessible by all members of the NASA family and contractors.

We now have training in our regular training program such that each NASA employee is required to undergo annual training on Foreign National Access Management, on export control.

We have a counter-terrorism, counterintelligence, face-to-face meeting among all of our NASA Center folk, we do that every year. Last year we did it at the Johnson Space Center in November. I went to that meeting. Also present at the meeting were senior officials from the FBI and a number of other intelligence agencies. They presented to us, they presented some of the training.

And going back to the certification of Chinese when we work with them, it is my intention to visit with Director Comey at the FBI to make sure that the certification process that we have in place meets his approval and that, you know, he is happy with the way we are doing it.

So I would say that if you go down to the bottom of the rung, you will find that people, they understand the importance of control of our vital resources and protection of our classified and sensitive information. So I think we have done quite a bit.

Mr. PALAZZO. Well, Administrator, I am glad you are taking it a lot more serious. You know, in the private sector, if an employee allows a laptop to walk off with 10,000 of their employees' sensitive information, that employee is likely going to be fired.

And so, I mean, it seems like throughout the Federal government, not just, you know, NASA, but there is not a lot of accountability. And of course when you see agency heads committing all kind of awful stuff, then, you know, it is kind of hard to punish the people down beneath them, but this is important stuff. Proprietary information to allow America to maintain its competitive edge, to maintain our leadership in space, you know, a slap on the wrist. And I am going off on some other agencies. There needs to be some teeth in holding people accountable for what they do.

And, Administrator, I will also mention a very successful 500-second RS–25 flight engine test at Stennis Space Center.

Mr. Chairman, if you have not been to Stennis Space Center, it is an open invitation. I would love to host you for a day and hopefully we can coordinate it around a test. Who knew NASA could make it rain and they do that with some of their engine tests.

And of course the whole committee is invited as well, Mr. Honda.

Mr. HONDA. Thank you.

Mr. PALAZZO. I yield back.

Thank you, Mr. Administrator.

General BOLDEN. Thank you very much.

FOREIGN NATIONAL ACCESS MANAGEMENT

Mr. CULBERSON. Mr. Palazzo is right, it is extraordinarily important to protecting the nation's space program and our technology from penetration by foreign agents, it is very important. And I know there was a problem at Ames, for example, and letting foreign nationals come into the facility.

So you mentioned, General Bolden, I heard you say Foreign National Access Management. I hope you have got procedures in place to essentially keep foreign nationals out of NASA Flight Centers and they don't get access to——

General BOLDEN. Mr. Chairman, I cannot stand here and say that is true, that is not true. We have foreign nationals who operate on NASA facilities every day, we have foreign nationals who may actually be NASA employees like every other agency of the Federal Government.

Mr. CULBERSON. Well, in particular the Chinese.

General BOLDEN. So I understand what you——

Mr. CULBERSON. The Chinese are the ones we are most concerned about.

General BOLDEN. The Chinese, that is different, yes.

Mr. CULBERSON. So no Chinese foreign nationals are getting access to NASA Flight Centers or computers?

General BOLDEN. No foreign nationals are getting unauthorized access to any classified material, sensitive material. No, none, zero.

Mr. CULBERSON. OK, thank you.

General BOLDEN. But, Mr. Chairman, I want to be very clear, no unauthorized access. Any time anyone who is not an American, in fact even American citizens have to go through a very stringent process to be allowed to have access to classified and sensitive material. That program is much more robust for a foreign national.

So I just don't want to lead you to believe that we have put a wall up and only Americans are going into bases.

Mr. CULBERSON. But the ones we are most concerned about are the Chinese.

General BOLDEN. Yes, sir.

Mr. CULBERSON. Because the Chinese space program is owned lock, stock and barrel, controlled by the People's Liberation Army. It is a military program designed to help them better target their ICBMs at the United States and they have a long history of stealing our technology. And it is just unacceptable the level of cyber theft and espionage the Chinese have been engaged.

And our predecessor, Frank Wolf, very wisely and with a lot of foresight, included language in our bill which we have kept and strengthened, that in Section 531, General Bolden, governs NASA's bilateral activities with China.

And I wanted to ask, if you could, sir, to please explain the process that NASA uses to ensure compliance with Section 531, which in part states that NASA must certify that these bilateral activities, these meetings, pose no risk of technology transfer or other information with national security or economic security implications to China or to a Chinese-owned company. How does NASA ensure compliance?

General BOLDEN. Yes, sir, and I made reference to this a little bit earlier. In order to follow the law pursuant to Section 531, we actually use an independent third party tool to execute our foreign national investigations. The tool is called Visual Compliance and that allows us to look at, among other databases, but there are five FBI databases, there are several Department of Treasury databases, those from the Department of Commerce, Department of Homeland Security, the State Department, Arms Export Control Department lists, and on and on and on. And so that is the process that we use for every single person that I put on a certification letter to you.

And as a result of some additional direction that came in Section 531, I now also provide a copy of that certification letter to the Director of the FBI, it goes via email transmission to—it doesn't go to Director Comey personally, but it goes to his executive secretary and it goes to the Section Chief of the FBI headquarters Counterintelligence Division, who right now is Mr. Crouch.

And as I said, my intent some time after this hearing is to actually sit down or at least, maybe not sit down, but talk to Director Comey and make sure that this process that I just explained to you meets the requirements and the needs of the FBI, so that they can feel that what we are certifying is in fact accurate.

Mr. CULBERSON. Right, because the reason that new language was added was to be sure that you are not just telling the FBI, but that you are involving them. That we want you to be able to get back from them and for them to be able to tell you this looks like it is okay or that is not okay.

General BOLDEN. Yes, sir.

Mr. CULBERSON. Let me ask, if I could—well, let me go to Mr. Honda, I have gone over a little bit.

ARC JETS

Mr. HONDA. Thank you, Mr. Chairman. I appreciate it.

Two things. When we were at NASA we visited a gadget into which we climbed, it is called the Arc Jet. And the function of that is to determine pressure andtemperature of reentry of capsules and missiles, for that matter. And I understood that is probably the most unique piece of equipment that we have, but it isalso that we are far behind in keeping it up and maintaining it.

And I just wondered whether if these Arc Jets are not capable of recreating the actual temperature and pressure that we anticipate, then how are we going to be able to ensure that that facility

will be upgraded so that the return will be safe for reentry of our astronauts in the capsule.

General BOLDEN. Mr. Honda, you give me an opportunity to talk about something that is near and dear to my heart. The Arc Jet about which you speak, in basic terms, it is a wind tunnel. And it is a wind tunnel that we generate incredible heat inside it.

Mr. HONDA. Ten thousand degrees.

General BOLDEN. So we are looking at thousands of degrees. And we are looking at the ability of a nose cap, for example, or something, the nose of a missile, to be able to withstand the heat and pressure of reentry.

The upgrade on the Arc Jet facility comes under a portion of our budget that is called Construction of Facilities and Environmental Compliance and Restoration, and that just happens to be a part of the budget that both the Congress and the Administration like to use as a bank to which they can go. So I would say when——

Mr. HONDA. Could you say that again?

General BOLDEN. I have used the term bank. It is a place——

Mr. HONDA. It is a fund that we go to.

General BOLDEN. It is a fund that everybody likes to go to because it is, quote-unquote, "not important." It is very important. It is because in that fund it is where safety and mission assurance, engineering, construction of facilities, upgrade to facilities is all book kept, and salaries.

And so when we take money from Safety, Security, and Missions Services (SSMS), when we go into that fund to take out a few million dollars, then what we have to do, what Mr. Eugene Tu out at Ames has to do is decide, okay, I am going to delay upgrade on the Arc Jet facility for one more year because I do not have the money to do that.

Mr. HONDA. This has some relationship to our discussion about multiple-year funding and multiple-year procurement.

Multiple-year procurement requires that we have the funds so that we can lay it out there in the future for that one year's allotment. Multiple year means that, you know, we can have some certainty that we can have a budget that we can count on so that Dr. Tu will be able to keep this Arc Jet performing at a place where we can assure that the reentry of our capsules will be tested in an appropriate way.

And so I think that it is a small piece, but without properly maintaining it and keeping it up to date, we get to Mars and we come back, if we come back and we hit that atmosphere and that is the piece that is messed up, I think it would be, you know, that is the one piece that we have to really pay attention to, even though the budget may not be—it is a budget that we keep dipping into to say, oh, we will take care of it later. But, you know, if we want to anticipate astronauts coming back and not watching them burn up on reentry, then we have to take care of that regardless of what kind of funding mechanism we have.

So I just wanted to make that point.

General BOLDEN. Yes, sir.

COMMERCIAL CREW SAFETY

Mr. HONDA. And connected to that, we talk about commercialization too. There have been a couple of commercial cargo explosions. And what are some of the things that we are doing to make sure that when we do send astronauts up using commercial launches, what are we doing as NASA to ensure that those astronauts that we do send up are going to be safe and that their launches are going to be safe in two years?

General BOLDEN. Mr. Honda, just as we did from both, in fact all three, we had three cargo mishaps, we lost a Progress vehicle, we lost a Dragon, and we lost a Cygnus all in a 12-month period of time. From each of the accidents, we had NASA personnel who were part of the accident investigation team. We either did our own supplemental investigation in addition to being part of the team or in the case of the SpaceX accident, since they have a number of different contracts with us and they have ongoing launches, not just for space station, then we are constantly involved with them.

But in all three cases we were able to satisfy ourselves that we understood what the root cause of the accident was, that they were taking appropriate actions to ensure that that cause was taken care of, was corrected or remedied, and that we would be able to go fly again.

I think everybody knows, we accept more risk with cargo than we will ever do with crew. So we already, you step up your safety requirements, if you will, your criteria for a human-rated launch much more than you do for a cargo launch.

But we feel that we have the correct amount of insight and in some cases oversight with both Boeing and SpaceX right now to ensure—I will say Boeing, SpaceX and the Orion Program team, because they are all three the same in our eyes. We are going to have astronauts on all three vehicles and so they have to have the same level of safety and mission assurance, and we have to have the same amount of visibility into all three before we will launch.

ROLE OF AERONAUTICS CORPORATIONS

Mr. HONDA. And if I may, what role, if any, does Aerospace Industries have——

General BOLDEN. The corporation?

Mr. HONDA. Corporation.

General BOLDEN. Aerospace is an FFRDC for the U.S. Air Force and they are—I have the Office of Safety and Mission Assurance and I think that Aerospace is in fact effectively the Office of Safety and Mission Assurance for the Air Force in most of their missile launches. I could be incorrect, but that is the way that I look at them.

And so we consult with Aerospace frequently, because with SpaceX again as an example, because both the Air Force and NASA use SpaceX, our Safety and Mission Assurance organization and our Office of Chief Engineer work hand in glove with Aerospace all the time, because sometimes neither of those three organizations has the sufficient number of people to cover everything. So Aerospace may cover something and debrief us, we may cover something and debrief them, but they work together all the time.

The present CEO of Aerospace, Dr. Wanda Austin, hosts a safety quality summit, I think it is twice a year. And Robert Lightfoot, who is the senior civil servant in NASA, he is the associate administrator or in a civilian company he would be called the chief operating officer, Robert attends that summit each year along with some of the folk from our Safety and Mission Assurance organization and the Chief Engineer's Office.

And so that there is constant interchange of ideas and experience with Aerospace, but they are not technically in our chain of command, if you will.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you.

Mr. Palazzo.

FLAT BUDGETS

Mr. PALAZZO. Well, Mr. Chairman, real quick. You know, we are talking, you mentioned flat budgets and it is kind of bad that NASA has been stuck on flat budgets. And our facilities directors, and as well as NASA and the administration, have done a good job with the flat budgets that we have given. And that just makes me want to make a few comments.

One, you know, we are $19 trillion in debt as a nation, but I don't think NASA's spending on deep-space exploration and low-earth orbit is what is driving those deficits, nor is our Department of Defense spending, investing in our men and women in uniform so they too can have the tools and training to do their job and come back home to their loved ones, but it is the out-of-control mandatory spending.

And in Congress, I mean, I know that NASA can't fix it, this Administrator can't fix that or others, but the American people should be demanding of Congress that we rein in the out-of-control spending, but we don't even have a vote on it because it is on autopilot, it is mandatory. And it is sad, because it is keeping us from doing the hard things at NASA, the great things, and funding, you know, not only just NASA, but also our military at levels that we need to to secure our nation.

So I hope one day we have that conversation and we can get past it, because we have got to curb the $19 trillion or we won't be having too many fun discussions on funding NASA's future ambitions. There won't be a Mars trip, there won't be a back-to-the-moon, there won't be America's leadership in space. We will be challenged and we don't know how we will come out if we don't fix our national debt.

And if we start today, then it is achievable. If we keep kicking the can down the road until tomorrow, it just gets harder and harder and harder.

So that was just more of a comment than anything, because that is something that is always, you know, keeping many of us up at night.

And again, Administrator, we appreciate your career in the United States Marine Corps, as well as at NASA.

General BOLDEN. Thank you, sir.

Mr. PALAZZO. Thank you.

General BOLDEN. Semper Fi.

Mr. PALAZZO. Semper Fi.

COMMERCIAL CREW MILESTONES

Mr. CULBERSON. Thank you very much.

Administrator Bolden, just a couple more followups.

On the commercial crew program, I wanted to ask if any of the fiscal year 2016 milestones slipped into 2017 or beyond on commercial crew.

General BOLDEN. Mr. Chairman, I will take that for the record.

To my knowledge, none have slipped that we didn't ask to be slipped for one reason or another, or that we didn't coordinate, you know, with the providers to slip it, because it would be—but I will take that for the record.

Mr. CULBERSON. Which milestones do you recall——

General BOLDEN. That is why I said I don't——

Mr. CULBERSON [continuing]. Slipped?

General BOLDEN. I don't think any slipped, but that is why I said, you know, when you talk about, sometimes people use the term slip when in fact we purposely moved something to a later date to accommodate some other test.

So what I would like to do, if it is okay with you, is to take it for the record——

Mr. CULBERSON. Yes, sir.

General BOLDEN [continuing]. And then tell you how any milestones that were scheduled to be done in 2016 are now being done in 2017 and why.

NEXT GENERATIONS ROCKET PROPULSION

Mr. CULBERSON. I wanted to also ask about the next generation rocket propulsion.

General BOLDEN. Yes.

Mr. CULBERSON. As you look into the future, and the one aspect of the asteroid mission that I think is particularly exciting is the development of the next-generation rocket propulsion, so I want to ask about NASA's work on not only solar electric, nuclear electric, but then also ask about the level of plutonium that you have available.

There is only, as I understand it, about 35 kilograms currently or 77 pounds of plutonium-238 set aside for NASA missions, and this will only support about two or three NASA missions through the middle of the 2020s.

Are you satisfied with the level of funding that you have to understand that the Department of Energy has wanted NASA to take the lead on this? We made sure that you had funding for plutonium-238 production in your 2016 bill.

What do you need from this committee and the Congress in order to make sure that you have got a sufficient supply of plutonium-238 for future missions and which missions do you expect to use plutonium for beyond the 2020, Mars 2020?

General BOLDEN. As my memory serves me, Mr. Chairman, we have sufficient funding and sufficient sources of plutonium for the missions that are in NASA's plan right now, Mars 2020 being the next mission that will require nuclear fuel.

And in a conversation with Dr. Grunsfeld, the head of the Science Mission Directorate, yesterday when we were talking about Juno that arrives at Jupiter here on Independence Day, you probably know that Juno is not nuclear-powered. Juno is powered by solar arrays, new-generation solar arrays, giant ones. But according to Dr. Grunsfeld yesterday, it is because of the work that we did on Juno and the success of those solar arrays that our team, along with JPL, is now leaning toward solar electric propulsion—solar power, not solar electric propulsion, solar power for Europa, which would mean that we would not need nuclear power for the Europa mission.

But that again, as I mentioned, you know, we won't know that until 2018 when we get to preliminary design review and finish out the formulation of the mission, but that is where it is leaning right now.

Mr. CULBERSON. If you could, talk to us about the next generation of rocket propulsion. What do you envision being developed to succeed chemical propulsion and what are you doing today to develop that next generation?

General BOLDEN. When people ask me about going to Mars and what are the challenges, I tell them radiation is one, time is another one. So we need game-changing propulsion, game-changing in-space propulsion.

We are now funding at a very low level development or research on what we call low-grade nuclear fuel, so that we do not have to go through the complicated process that we do now to get, you know, the type of enriched fuel that we use today. That holds out some hope.

There are other systems. People are looking at advanced solar electric propulsion. You have people like Dr. Franklin Chang Diaz has a rocket that is called VASIMR, it is variable specific-impulsed thrust, which is a constantly thrusting ion engine, you know, that we are funding. We are funding the upgrade of a laboratory where he is doing testing now to just see if he can get it ground tested and then we will go see what happens after that.

That type of propulsion systems bode well for the future. But nuclear electric I think is the one that most people tell me is probably going to be what we need, but we have got to get the fuel issue solved first, you know. But we are making slow progress.

Mr. CULBERSON. Mr. Honda.

SPACE LAUNCH SYSTEM

Mr. HONDA. Thank you, Mr. Chairman.

I have been learning quite a bit over the past few weeks. I would like to get some of your thoughts on the comments that were made about Space Launch System a couple years ago by a gentleman by the name of Chris Kraft, NASA's first flight director. He said that the operating costs of SLS, quote, "will eat NASA alive." He lamented that while other existing rockets had become reliable through frequent use, the SLS will not achieve that level of reliability because, in his view, we won't be able to afford to launch it more than once a year, if that.

On the subject of future human space flight, missions to deep space, Mr. Kraft has also questioned why we cannot use our exist-

ing launch vehicle capabilities and put vehicles in space in pieces like we did with the space station.

So two questions. How do you respond to these sorts of concerns about the Space Launch System? And what is NASA doing to work with industry and Government partners to develop the spectrum of missions beyond EM–1 and EM–2 to fully utilize this enormous national asset that will be coming on line in only a few short years?

General BOLDEN. Mr. Honda, you know, Dr. Kraft is a role model and a mentor for me. He was my Center Director when I first became an astronaut and went to the Johnson Space Center. He is an incredible human being. From Virginia Tech, by the way. I did not know that until a short time ago. We always think about everybody comes from Harvard and Stanford and stuff. It is a pretty good institution down there in Blacksburg.

But his statement about SLS is, I think, and I cannot speak for Dr. Kraft, I think a lot of people's statements like that are based on how we operated when they were in charge or when they were around, that is a long time ago. SLS represents the best technology that we have today to leave the planet.

I think most people would tell you, we don't have a way other than chemical propulsion today to get off the planet, and we would probably always want to use something like an SLS. When you talk about the Europa mission, and while I am not making a commitment to you, Mr. Chairman, I want you to understand what I am saying here, SLS, it represents an incredible promise and potential not just to human space flight, but to scientific space flight.

You know, the reason we are all attracted to SLS for our Europa mission or any outer planets mission is because, you know, 9 years to get somewhere or 8 years to get somewhere or 7 years, that is a long time. The team, it is hard to hold then intact, you are paying for them. It is much cheaper if we can use, if it turns out that SLS is able to be used for a Europa mission, we are talking about a 2½ year mission. You know, that is 5 years we have saved in transit time, in salaries, in keeping a team enthused, you know, not shutting the vehicle down the way we did with New Horizons.

There are a lot of good reasons to do it, but that is not a commitment to SLS. I want to make sure you understand that, Mr. Chairman. You told me to make sure it happens, I am trying.

But in response to that, even if it is in the law, if I found that it were not the right thing to do, I would come to you and say, Mr. Chairman, can we review this policy, because that is not in the best interest of the American taxpayer.

So we are following the law and we will always follow the law, but sometimes things change and you go back and you revise the law. It is like our Constitution, that is why we have amendments. We find that the Founding Fathers were not the brilliant, maybe they were not as smart as we thought they were the first time around or something like that. I don't know.

Mr. HONDA. Of course, based on history too.

General BOLDEN. That is exactly right. Yes, exactly.

Mr. HONDA. I just needed to ask the question, just to clear up some of the questions I had in my mind.

General BOLDEN. Yes, sir.

Mr. HONDA. And I think that the explanation is——

General BOLDEN. And I hope I answered the question.

Mr. HONDA. No, no.

General BOLDEN. Because Dr. Kraft is——

Mr. HONDA. No, I get what you are saying.

General BOLDEN [continuing]. Way more brilliant than I am and knows this stuff a lot better than I do, but I have the advantage of a team around me that he didn't have.

Mr. HONDA. Sure.

General BOLDEN. You have to remember, most of us forget, I have a very mature leadership team. When Dr. Kraft was in Mission Control and when he led the Johnson Space Center and we went to the moon, most of the people were 20 years old. They didn't know anything.

Mr. HONDA. Well, that is the difference like between myself and my son. When I launched an airplane, it was made out of balsa wood and I pushed it off, he uses a battery now and he has got all kinds of things at hand.

So I just wanted some sort of clarification in my mind.

General BOLDEN. Yes, sir.

Mr. HONDA. Thank you.

CHAIRMAN'S CLOSING REMARKS

Mr. CULBERSON. Well, General Bolden, we want to thank you again for your service to the country and for the service you have given to NASA, the leadership. It has been a privilege for us to work with you. And we will have a number of questions that we will submit for the record, sir.

But again, from the bottom of our heart, we genuinely appreciate your service to the country. And this subcommittee and the Congress strongly supports the men and women at NASA and we will do everything we can to make sure you have got the resources you need to achieve all that is on your plate, and to ensure that the American space program is the very best in the world bar none.

General BOLDEN. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you very much, sir.

The hearing is adjourned.

The Honorable John Culberson
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the NASA FY 2017 Budget Request

Question 1:

Orion

The request for Orion does not include sufficient funds to develop and test systems on EM-1 necessary to support human life, such as seats, display screens and other equipment that will be used by humans on EM-2. Please explain NASA's rationale for not fully testing all human rated systems on EM-1 prior to flying humans on the EM-2 mission. Is NASA confident that its current plans to test human rated systems for the first time with humans on EM-2 is sufficient to ensure that all systems work properly?

Answer 1:

NASA is executing an incremental development and testing approach with Orion with the Exploration Flight Test-1 (EFT-1) article as the initial configuration and subsequent configurations (Exploration Mission-1 EM-1 and Exploration Mission-2 EM-2) building up to the needed crew capability. The test plan is logical and technically rigorous, with each step building confidence toward the first crewed flight on EM-2. EFT-1 tested the first environmental control components, including the active thermal control system pump package, the ammonia tanks, cold plates and valves. EM-1 will include the next phase of passive environment control, and EM-2 development will complete the active environmental control and life support systems, and adding the crew accommodations, including display and control systems. NASA did not request additional funds because it is not effective to add these capabilities without a demand or consumption on those capabilities, which would not be available on EM-1 and would leave the capabilities virtually untested (e.g., no one to breathe the oxygen generated and then exhale carbon dioxide and humidity into the scrubbers, and no one to interact with the displays). Development of life support components flying on EM-2 has already begun via internal Government efforts (these efforts include component development, build, and test for the Orion spacesuits), and multi-thousands of testing hours being conducted now aboard the International Space Station (ISS). NASA is confident that this development plan is sufficient to ensure that Orion's life support and other crew systems will work properly on EM-2. Additionally, the EM-2 mission planners are considering several techniques for mitigating environmental control and life support system (ECLSS) failure exposure before fully committing the crew to lunar orbit on that flight.

Question 2:

Commercial Crew

Question 2a)Have any fiscal year 2015 commercial crew milestones slipped into subsequent fiscal years, and if so, which milestones and to which fiscal year?

Answer 2a):

Following the successful resolution of the Commercial Crew Transportation Capability (CCtCap) contract protest in January 2015, the Commercial Crew contractual milestone dates were re-baselined. Since that time, the following milestone's deliveries moved from FY 2015 into FY 2016:

Milestone	From Date	To Date
Boeing Structural Test Article Test Readiness Review - Part A	September 2015	November 2015

This Boeing milestone was split into two parts (A and B) to align the readiness verification to the milestone readiness indicators. Segmenting this milestone provides NASA an earlier opportunity to review/comment on the more mature items, and NASA the opportunity to help ensure the constraints list is right for Part B.

Question 2b) Have any fiscal year 2016 commercial crew milestones slipped into subsequent fiscal years, and if so, which milestone and to which fiscal year?

Answer 2b):

Following the successful resolution of the Commercial Crew Transportation Capability (CCtCap) contract protest in January 2015, the Commercial Crew contractual milestone dates were re-baselined. Since that time, the following milestones have moved from FY 2016 into FY 2017:

Milestone	From Date	To Date
SpaceX Environmental Control Life Support System Integrated System Test	June 2016	November 2016
SpaceX Validation Propulsion Module Testing Complete	December 2015	March 2017
SpaceX Space Suit Qualification Testing Complete	September 2016	November 2016
SpaceX Flight Test without Crew Certification Review	September 2016	February 2017

These SpaceX milestone slips above are related to NASA-proposed requirement changes that impact design features in the Dragon vehicle. These changes were driven by the NASA medical community as they begin to better understand intra-cranial pressure changes and the effects on Astronaut vision from exposure to long-duration microgravity conditions. Negative acceleration during reentry along the longitudinal axis of returning crew members could increase the consequences of the phenomena observed in flight. Changing this requirement will impact the crew seat position in the capsule. SpaceX has accordingly proposed updates to several milestones dates to reflect preliminary assessments of these impacts which are still in formal review. This allows SpaceX and NASA to plan ahead for detailed certification activities this year.

FY 2016 Milestones are being evaluated on a continuous basis and additional updates will be provided in the Commercial Crew Program Quarterly reports.

Question 2c) When will the commercial crew contractors fly their first uncrewed test flights to the International Space Station – please include planned quarter and year for each contractor.

Answer 2c):

SpaceX plans to fly the first uncrewed demonstration mission of their Crew Dragon spacecraft in the third quarter of FY 2017. Boeing also plans to fly the first uncrewed orbital flight test of their Starliner-100 spacecraft in the third quarter of FY 2017.

Question 3:

Commercial Crew Anomaly

What processes has NASA instituted to ensure that all issues with the commercial cargo loss are ameliorated completely before commercial partners begin transporting humans to the International Space Station?

Answer 3:

NASA does not anticipate that the loss of SpaceX-7 will affect the timeline for the Commercial Crew Program (CCP), and the lessons learned from this event could provide early insight to any needed design changes. CCP uses a thorough process to verify that each and every NASA safety requirement is met by the contractor's design. This process includes design verification as well as hardware and software testing, and begins far in advance of any flights with human crew. By maximizing learning from this failure, we can help to ensure that a more reliable launcher is available.

Material for the Record
March 15, 2016, Hearing on NASA's FY 2017 Budget Request
before the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies

Material for the record by Chairman Culberson, regarding Europa AO science instrument on page 58-59

Question 1:

When, over the next few months, will you be announcing -- an announcement of opportunity for the science instruments to be included on the Lander for Europa?

Answer 1:

Over the next few months, NASA will determine the best plan forward to ensure that science instruments for a potential future lander would be mature and ready for payload selection. A key step in the process for selecting instruments is to identify the highest priority science investigations that can be accomplished on Europa with the proposed lander. NASA has established a Science Definition Team (SDT) to provide input from the broad science community and to help develop consensus science requirements. The SDT began its work in May 2016, with their final report due at the end of FY 2016.

In addition, NASA recently released a NASA Research Announcement (NRA) for the Concepts for Ocean worlds Life Detection Technology (COLDTech) Program. The COLDTech Program supports the development of spacecraft-based instruments and technology for surface and subsurface exploration of ocean worlds such as Europa, Enceladus, and Titan; however, it does not solicit instruments or technology for a flight opportunity. The goal of the program is to develop and reduce the technical risk of instruments and technology for potential future missions so that they may eventually be proposed in response to future Announcements of Opportunity (AOs) for flight missions. Mandatory Step-1 proposals for this NRA are due by June 17, 2016, and Step-2 proposals are due by August 12, 2016.

Material for the record by Chairman Culberson, regarding slips in commercial crew milestones on page 80

Question 2:

What FY 2016 Commercial Crew milestones have slipped into FY 2017 or beyond, and why?

Answer 2:

Following the successful resolution of the Commercial Crew Transportation Capability (CCtCap) contract protest in January 2015, the Commercial Crew contractual milestone dates were re-baselined. Since that time, the following milestones have moved from FY 2016 into FY 2017:

Milestone	From Date	To Date
SpaceX Environmental Control Life Support System Integrated System Test	June 2016	November 2016
SpaceX Validation Propulsion Module Testing Complete	December 2015	March 2017
SpaceX Space Suit Qualification Testing Complete	September 2016	November 2016
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These SpaceX milestone slips above are related to NASA-proposed requirement changes that impact design features in the Dragon vehicle. These changes were driven by the NASA medical community as they begin to better understand inner cranial pressure changes and the effects on Astronaut vision from exposure to long-duration microgravity conditions. Negative acceleration during reentry along the longitudinal axis of returning crew members could increase the consequences of the phenomena observed in flight. Changing this requirement will impact the crew seat position in the capsule. SpaceX has accordingly proposed updates to several milestones dates to reflect preliminary assessments of these impacts which are still in formal review. This allows SpaceX and NASA to plan ahead for detailed certification activities this year.

The Honorable Robert B. Aderholt
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the NASA FY 2017 Budget Request

Question 1 - Regarding the Space Launch System (SLS):

After several years of focus on the core stage and ground operations work, last year's bill included, with my encouragement, direction to spend no less than $85 million on the EUS (Exploration Upper Stage).

Question 1a) Have all of the FY16 funds been obligated? If not, by what date do you plan to obligate them?

Answer 1a):

The FY 2016 funding for Enhanced Upper Stage (EUS) development/Block 1B will be allocated as follows: $77 million for the Space Launch System (SLS) program; and $8M Ground System Development & Operations for facility modifications required for EUS. The SLS funding covers FTE civil servant labor for DDT&E, support service WYE contract costs, and preparations leading up to PDR and ultimately contract award. The SLS Program has obligated approximately $50 million on the EUS through March 2016 with the expectation to obligate the remaining $35 million in July 2016.

Under the President's Budget Request for FY 2017, Exploration Mission-2 (EM-2) would launch with SLS Block 1 using the Interim Cryogenic Propulsion Stage. The FY 2016 Appropriations Act directs NASA to develop the EUS for the second joint mission of the Agency's Space Launch System and Orion spacecraft. With this direction, and the funding provided in the FY 2016 Appropriations, the SLS Program will mature the EUS to the level of Preliminary Design Review (PDR), to be held near the end of calendar year 2016. This spring, NASA issued a sole-source request for proposal (RFP) to Boeing to determine the development and hardware costs associated with the EUS. NASA is also pursuing a sole-source request for proposal (RFP) to Aerojet Rocketdyne to support production of the first flight set of RL10 upper stage engines, the associated integration, and required human rating information for the EUS. Other contracting activity in support of EUS will likely follow later this year for the Universal Stage Adapter (USA). NASA will continue to assess implementation of EUS as we progress through the developmental cycle.

I am concerned about the fact that no specific funding amount is specified for EUS in the FY17 budget request. I think support in Congress for EUS being a part of the EM-2 mission has not waned.

Question 1b) As you work on the EUS, are you planning for the purchase of at least two of these upper stages? Or is the plan to purchase only one, leaving plans unclear for the upper-stage of later flights?

Answer 1b):

NASA issued a Request for Proposals (RFP) for the development of the Exploration Upper Stage (EUS) on EM-2 on April 20, 2016. The modifications to the ground infrastructure to support the Space Launch System (SLS) Block 1B configuration which uses the EUS would not be backwards compatible with the

SLS Block 1 crewed configuration, thus NASA plans to use the EUS for subsequent Exploration Missions flown by the Space Launch System (SLS). Strategies for procurement of core stages and EUS's following EM-2 will be determined later this year.

Question 1c) We are one year farther along in the work on SLS; I will ask some of the same questions I asked last year in hopes of receiving a more detailed response. With reference to your answers from last year, any assumed plan by the Administration to use a second ICPS for EM-2 would add a cost of something in the range of $400 million to human rate that stage - which will be used for only one human mission. As indicated in last year's bill, Congress expects missions subsequent to EM-2 to take full advantage of the superior capabilities of an EUS stage, and it is a better use of taxpayer money to human-rate the EUS.

On the assumption that Congress will continue to make up for inadequate SLS budget requests, and regardless of what the Administration is currently assuming about EM-2, please provide to the Committee a multi-year budget plan which shows amounts needed - specific to the EUS - for it to be ready and available for EM-2.

Answer 1c):

The SLS Program will mature the Enhanced Upper Stage (EUS) to the level of Preliminary Design Review (PDR), to be held near the end of calendar year 2016. This spring, NASA issued a sole-source request for proposal (RFP) to Boeing to determine the development and hardware costs associated with the EUS. NASA has also issued a sole-source request for proposal (RFP) to Aerojet Rocketdyne to support production of the first flight set of RL10 upper stage engines, the associated integration, and required human rating information for the EUS. Other contracting activity, which will be necessary to support the EUS, will likely follow later this year for the Universal Stage Adapter (USA). Design analysis has also begun to modify the Exploration Ground Systems (Vertical Assembly Building, Pad 39B) to accommodate the larger EUS. The Orion program has also incorporated EUS preliminary design loads into the vehicle design. NASA will continue to assess implementation of EUS as we progress through the developmental cycle.

NASA is in the process of developing estimates for EUS to be considered as part of the formulation of the FY 2018 budget request, based on the early design stage (prior to associated Preliminary Design Review and other assessments), as well as contract discussions that have not yet begun for all Block 1B elements. These estimate ranges are subject to further maturation during ongoing contract negotiation, technical design reviews, and near-term budget formulation processes. As a result, NASA is unable to provide a revised multi-year budget plan beyond that reflected in the FY 2017 budget submit at this time.

Under the President's Budget Request for FY 2017, Exploration Mission-2 (EM-2) would launch with SLS Block 1 using the Interim Cryogenic Propulsion Stage (ICPS). The FY 2016 Appropriations Act provides $85M for the Enhanced Upper Stage development, and the accompanying Explanatory Statement stipulates that the funding is "for development of an enhanced upper stage that is intended to be the human-rated upper stage engine for Exploration Mission (EM-2)" using the Space Launch System and Orion spacecraft.

Question 1d) Work on the core stage is nearing completion; what adjustments are being made by NASA regarding the apportionment of funding and FTE slots (oversight versus new engineering work, for example), to ensure that EUS work proceeds in a prompt manner?

Answer 1d):

Under the President's Budget Request for FY 2017, Exploration Mission-2 (EM-2) would launch with Space Launch System (SLS) Block 1 using the Interim Cryogenic Propulsion Stage. The Fiscal Year 2016 Appropriations Act directs NASA to develop the Exploration Upper Stage (EUS) for the second joint mission of the Agency's Space Launch System and Orion spacecraft. With this direction, and the funding provided in the FY 2016 Appropriations, the *SLS Program will mature the EUS to the level of Preliminary Design Review (PDR), to be held near the end of calendar year 2016. NASA has issued a sole-source request for proposal (RFP) to Boeing to determine the development and hardware costs associated with design development, manufacturing, and test of the first flight EUS. NASA has also issued a sole-source request for proposal (RFP) to Aerojet Rocketdyne to support production of the RL10 upper stage engines, the associated integration, and required human rating information for the first flight EUS (four engines and two spares). Other contracting activity in support of EUS will likely follow later this year for the Universal Stage Adapter (USA). NASA will continue to assess implementation of EUS as we progress through the developmental cycle.*

Question 1e) My question from last year, requesting to know what payloads could be launched on SLS in 2018 if Orion were not ready, was answered only with the response that NASA is focused on the SLS/Orion mission. Now that we are one year later in the process, were the KDP-C and CDR for Orion completed in 2015?

Answer 1e):

NASA announced completion of Orion's Key Decision Point-C (KDP-C) on Sept. 16, 2015. Orion's Critical Design Review (CDR) was completed at the Program level in October 2015, and briefed to the Agency Program Management Council (APMC) in March 2016 (however, a separate CDR for the European Service Module is not yet complete, and will take place in the summer of 2016).

Question 1f) Based on a year of progress since last year's hearing, what is the year-by-year budget needed for Fiscal Years 2017, 2018, and 2019 for SLS, Orion, and Ground Systems, separately, to ensure launch in 2018 of an SLS/Orion integrated capability? Have you included those amounts in your multi-year budget plans? Has there been any independent review of those plans, such as by GAO, or a request to perhaps utilize the services of Aerospace Corporation?

Answer 1f):

Please see table below. The President's FY 2017 Budget Request supports the launch of the Space Launch System (SLS) and Orion on Exploration Mission-1 (EM-1) in November 2018.

(in $M)	FY17	FY18	FY19
Orion	1,120	1,120	1,124
Space Launch System	1,310	1,361	1,485
Exploration Ground Systems	429	441	453
TOTAL	2,860	2,923	3,062

These amounts are included in the President s FY 2017 Budget Request. The SLS/Orion budget has historically been reviewed as part of the annual Government Accountability Office's (GAO) "NASA Quicklook." NASA has not requested a review by The Aerospace Corporation. The FY 2017 Budget Request was based on Agency Baseline Commitments for each of the three programs, which in turn was

informed by Standing Review Board assessments of program risks and implications for cost and schedule.

Question 1g) With reference to last year's hearing question response, what is the updated Orion development cost?

Answer 1g):

Per the Orion KDP-C, NASA is committed to a development cost baseline of $6.8 billion from October 2015 through the first crewed mission (Exploration Mission-2 EM-2). Development costs prior to October 2015 are approximately $ 4.7 billion. This is consistent with funding levels in the FY 2017 President's Budget Request.

Question 2:

I support the Europa program, and I support the FY16 bill language specifying the SLS rocket as the launch vehicle. Given how far away Europa is, it makes sense to use our fastest, and largest payload-capacity rocket.

With regards to planning missions, I think public interest and support for the agency is strengthened by lander missions.

a) Given the experience we have gained from Mars robotic missions and other work, do you think we cannot go ahead and plan a robust, successful lander mission to Europa, without doing other missions before that?

b) It seems that there could be cost and design advantages from including a lander component in the first mission to Europa. The cost of one launch instead of two, and the speed of receiving data obtained by a lander, are two possibilities. Do you agree? Are there others?

Answer 2:

NASA has initiated a study of lander concepts by JPL. Initial concepts included one spacecraft to carry both the flyby and the lander components. An Independent Review was held and the findings showed no advantage in this concept as well as excessive cost, risk and complexity growth. Given the lack of knowledge of the surface conditions of Europa, landing prior to reconnaissance cannot be justified. Ongoing studies include analyzing options for separate or co-manifested flyby and lander missions.

Question 3:

Congress appropriated $15 million for Small Launch Vehicle development.

This is not the same thing as the Flight Opportunities Program, in terms of the small grants which are focused on preparing small payloads for launch.

a) Who is under contract for the Small Launch Vehicle development work with FY16 funds, and what is the status of this program? Note: the only award somewhat related to launch vehicle development in the list of awards on the NASA web site was actually FY15 funds for a project mostly funded by the private sector.

b) What are the plans for FY17 funds for launch vehicle development work?

Answer 3a):

The Flight Opportunities program was established by 42 USC 18405 based in part on the recommendation of the National Academy of Sciences to revitalize suborbital research. The program's objective is to transform NASA missions and advance U.S. spaceflight capabilities by fostering the operational readiness of innovative space technologies and promoting the development of the commercial space industry. The program achieves these objectives by selecting promising technologies from industry, academia, and government, and testing them on commercial suborbital launch vehicles. This approach takes technologies from a laboratory environment and advances their maturity through flight testing, while also supporting the development of the spaceflight technologies and infrastructure created by the Flight Opportunities Program flight providers. The program supports flights for both externally funded payloads and NASA-funded technology payloads selected though NASA Research Announcements (NRAs). Space Technology also collaborates with other NASA programs to provide suborbital platform flights for research and/or technology demonstrations.

Since its inception, the program has selected promising space exploration and utilization technologies from industry, academia, and government, and demonstrates their technology readiness through flights on commercial launch vehicles. This program has taken technologies from a laboratory environment providing them the opportunity to develop critical flight heritage, while also stimulating the development and utilization of U.S. commercial spaceflight capabilities and infrastructure. The Flight Opportunities program has also recognized that the nascent commercial nano-launch market is a natural extension of the emerging commercial suborbital launch market. In FY 2015, the program began to evolve its mission to also include helping foster U.S. commercial nano and small launch systems in addition to its mission of helping foster U.S. commercial suborbital launch systems and space technologies.

Answer 3a) The Flight Opportunities program is in the process of negotiating partnership agreements with companies that were competitively selected through STMD's 2015 Announcement of Collaborative Opportunities (ACO) solicitation to work with NASA on development of commercial nano and small satellite launch systems and associated technologies. The FY 2016 funding required for these nano launch technology development projects is approximately $5M pending final negotiation. Through the 2015 ACO solicitation, NASA selected six technology development projects to enable nano launcher system design and development. These projects span approximately two years, covering both FY 2016 and FY 2017. These nano launcher technology development projects were awarded to: Generation Orbit Launch Services (two awards), Virgin Galactic, UP Aerospace Inc., Garvey Spacecraft Corporation, and Dynetics. This new initiative is intended to help increase the availability and capability of U.S. commercial launch services by developing technologies for future nano launch systems. Additionally, NASA plans to release a Tipping Point solicitation in the summer of 2016 that will further expand and stimulate commercial nano and small satellite launch technology development through public private partnerships. These new projects will be multi-year awards.

Outside of the Flight Opportunities program, in October 2015, the NASA's Launch Services Program (LSP) has awarded Venture Class Launch Services contracts to provide nano and small satellites launches to low Earth orbit to: Firefly Space Systems, Rocket Lab USA, and Virgin Galactic.

Answer 3b):

In FY 2017, the Flight Opportunities Program will continue to enter into partnerships to spur the development of nano-launch orbital capabilities of small spacecraft launch systems. The aim of the effort

is to enable emerging companies by sharing NASA expertise and relevant technologies to provide the Nation with frequent and cost effective access to space for small payloads.

Question 4:

Space Station Crew Transportation.

As a follow up to last year's questions:

Question 4a) From last year's answer, and a handout provided to staff, development costs, prior to payment for crew flights, are about $5 billion. That figure, divided by 86 million (a recent cost per seat, provided at a staff briefing), is 58 seats. Please list the number of American astronauts sent to the International Space Station (ISS), listed as a sum for each calendar year, beginning in 2009.

Answer 4a):

Please see table below with the number of NASA and U.S. On-Orbit Segment (USOS) astronauts who flew to the International Space Station (ISS) as part of Expedition crews – by calendar year – from 2009 to March 31, 2016.

CY	2009	2010	2011	2012	2013	2014	2015	2016*
NASA and USOS Astronauts	6	6	6	6	6	6	5	1

*through 3/31/16

Question 4b) Your answer last year indicates that we spend about $500 million a year to launch astronauts on Russian systems. $500 million divided by $86 million is 5.8. Do we plan to send more than 6 astronauts a year to the ISS? If so, what is the total expected cost of that transportation per year?

Answer 4b):

NASA anticipates increasing the total on-orbit ISS crew size from six to seven once the U.S. commercial crew vehicles are operational (or approximately two additional crew slots per year).

The FY 2017 President's Budget Request for Space Transportation (which includes Commercial Crew and ISS Crew and Cargo) is shown below. NASA assumes two crew flights per year.

(in $M)	FY17	FY18	FY19	FY20	FY21
Space Transportation	**2,758**	**2,475**	**2,119**	**2,144**	**2,214**
Commercial Crew	1,185	732	173	36	36
Crew and Cargo	1,573	1,743	1,946	2,109	2,178

Question 4c) The government is investing $5 billion in the development of Space Station Crew Transportation. What is the ratio of private-company dollars to taxpayer dollars being paid as part of that development?

Answer 4c):

According to the 2013 NASA Inspector General report, NASA's Management of the Commercial Crew Program: "On average, the three Commercial Crew partners are contributing under 20 percent of the CCiCap development costs for their spaceflight systems." For the current phase of the program, Commercial Crew transportation Capability (CCtCap), company investment is not explicitly calculated. Under a firm, fixed price contract, the contractor will invest any amount greater than the negotiated price for the services to deliver the contracted service to the Government.

Answer 4d) 58 divided by eight (as in, the years inclusive of 2017 to 2024) is a bit more than 7 astronaut flights per year. Thus, the development costs alone, compared to the payment for seats on the Soyuz, is almost enough to pay for astronaut seats for the entire remainder of the life of the ISS.

What intellectual property rights have been secured by NASA? For example, if a beneficiary of taxpayer investment decides to sell their company to another country with interests in LEO space activity, is there any protection for the U.S. taxpayer, or do we have to, in effect, start all over again paying majority-taxpayer-dollar-funded space transportation development programs?

Answer 4d):

NASA's CCtCap partners are under firm fixed-price contracts to provide crew transportation services to and from the ISS. The partners own and operate their own vehicles, and they retain ownership rights in intellectual property (including the right to sell the technologies to others) even under FAR contracts, and the Federal government receives a license to support future government use. The CCtCap contract also allows NASA to order any additional data we want, during the contract and up to three years after the contract ends. Also the contract, like any U.S. Government contract, cannot be transferred to another entity without the Government's concurrence.

Question 4e) I think the latest cost estimate of astronaut flight on commercial systems was $55 million per seat. What was the original offer price, per seat, from the commercial providers?

Answer 4e):

The pre-negotiation per-seat offer price for the two CCtCap systems is considered Sensitive But Unclassified because it would give each company insight into its competitor's pricing.

Question 5:

I want to emphasize again my strong concern regarding the fact that NASA committed U.S. taxpayers to an excessive process of soil treatment at the Santa Susana Field Laboratory site. NASA could have offered to treat the soil to RESIDENTIAL levels, which, as the name implies, are safe for residences and playgrounds. Instead, NASA is spending money to process soil to a BACKGROUND level.

Question 5*a) Question: What is the estimated total cost of this cleanup?*

Answer 5a):

Through FY 2015, NASA has spent in excess of $100 million in the characterization and interim cleanup actions at the Santa Susana Field Laboratory (SSFL). Near term activities include completion of the soil and groundwater investigation fieldwork and associated reports, demolition of obsolete structures, cultural resource evaluations, and development of cleanup action plans. The FY 2016 budget plan is $16 million and the FY 2017 budget request is $38 million. Once soil cleanup actions start, NASA estimates that the total cost of the cleanup will be from $400 - $500 million. Since groundwater site characterization activities are still ongoing, the selection of cleanup remedies has not yet been determined and final cost estimates have not been developed. As an interim action, NASA has installed a groundwater pump and treatment system and routinely monitors groundwater wells. It is estimated these long-term monitoring, operations and maintenance phase will cost approximately $1 million per year for 30 (or more) years. Below is NASA's estimated total costs to complete by major work tasks.

Soil Cleanup to AOC Standard	$330 million
Groundwater Cleanup	$50 million
Cultural Resource Management	$30 million
Demolition	$15 million
Total Estimated Cost to Complete	$425 million

Question 5b) Question: There has been concern by Native Americans that this area not be disturbed. What is the legal status of this concern?

Answer 5b):

NASA has consulted with the California State Historical Preservation Officer as legally required under the National Historical Preservation Act. In addition, NASA has engaged in consultation with Native American stakeholders organized under the SSFL Sacred Sites Council. Several distinct tribal groups have ancient cultural ties to the SSFL. To date, the Santa Ynez Band of Chumash Indians (a federally recognized tribe), have specifically declared portions of the site to be sacred lands under Executive Order 13007. In addition, the Chumash also alerted the Native American Heritage Commission that the entire SSFL site is sacred land and a traditional cultural landscape. On March 23, 2016, the Chumash sent a letter to Congressman Steve Knight (R-25th/CA) requesting that he introduce legislation supporting designation of the SSFL as a national monument under the Antiquities Act. In April of 2015, the Chumash sent a letter to the NASA Administrator seeking support for national monument status. The Administrator responded that the issue was outside NASA's statutory authority and mission, but that he would direct the request to the Department of Interior. A national monument designation would likely impact the level of cleanup required for the site.

Question 5c) Your response of last year indicates that you may be addressing Native American concerns by altering the process. If that is so, what are you doing, and how has that added to the total cost?

Answer 5c):

NASA is addressing Native American concerns within the bounds of our obligations under the 2010 Administrative Order on Consent (AOC) with the State Department of Toxic Substance Control (DTSC). Extensive archeological investigation and monitoring have been and are being conducted. NASA is in constant communication with tribal authorities through the Sacred Sites Council. The AOC process provides in the underlying "Agreement in Principle" that SSFL "Native American artifacts that are

formally recognized as cultural resources" are exceptions to the requirement for clean up to a level "as close to local background as practicable . . .." NASA is working with state regulators to determine how the cleanup process under the AOC will comply with this provision. This work will not significantly add to the total costs but could result in lower costs by identifying areas that can be left alone and protect cultural resource while still meeting AOC requirements.

Question 5d) Has NASA inquired of Native Americans whether their concerns could be better met by the far less intrusive approach of cleaning to the RESIDENTIAL level instead of the BACKGROUND level?

Answer 5d):
NASA is legally required to comply with the 2010 AOC provisions. Given that the state regulators are the enforcement authority under the AOC, NASA has not inquired of the tribes whether a RESIDENTIAL level cleanup would address their concerns. NASA will continue to work closely with the state and the Sacred Site Council regarding the cleanup levels, working to be protective of both the environmental and Tribal concerns.

Question 6:
Based on recent years, eight more years of ISS sustainment would cost a minimum of $32 billion dollars. Obviously, the level of funding could benefit Science Directorate programs, as well as Human Exploration programs. Habitat work in or near the Moon is, for example, merely one way of augmenting life science work done up to now on the ISS.

Question 6a) What does the agency hope to achieve for that sum of $32 billion, and, is there consideration to terminate the ISS sooner and shift funds to cis-lunar work which would advance our knowledge of life science, and advance our knowledge of engineering systems needed for living and working in space beyond LEO?

Answer 6a):

The ISS is vital to NASA's mission to extend human presence into the solar system. Many systems needed to enable human deep space exploration will be tested first on ISS. In order to prepare for human expeditions into deep space, we must first use the unique environment of ISS to conduct the research and technology demonstrations necessary to keep our crews safe and productive on long-duration spaceflights. The ISS is NASA's only long-duration flight analog for future human deep-space missions, and it provides an invaluable laboratory for research with direct application to the exploration requirements that address human risks associated with deep-space missions. It is the only space-based multinational research and technology test bed available to identify and quantify risks to human health and performance, identify and validate potential risk mitigation techniques, and develop countermeasures for future human exploration. NASA is focused on learning how to keep astronauts healthy and productive on ISS, so that the Agency may progress on to future deep-space missions beyond low-Earth orbit (LEO) and into the proving ground of cislunar space.

ISS is critical for both human health and performance research required to keep our crews safe and productive on long-duration missions, and for the development of exploration technologies to be incorporated into those missions:

- *NASA uses the Human Research Program's (HRP) risk reduction plan, which is designed to chart progress in reducing the risk in 25 human health and performance areas important to deep-space*

exploration, including a mission to Mars. These plans are coordinated across the Human Exploration and Operations Mission Directorate and the Space Technology Mission Directorate.

- *NASA has an ISS Technology Demonstration Plan delineating key exploration capabilities needed for future missions both to cislunar space and to Mars. These rely on ISS as the sole means for in-space testing over the next several years. These capabilities include: Environmental Control and Life Support System (ECLSS); Environmental Monitoring; Extravehicular Activity (EVA); Fire Safety and Response; Crew Health and Performance Technologies; Thermal (including Cryo); Power and Energy Storage; Communications and Navigation; Structures and Materials; Radiation Monitoring and Shielding; Autonomous Operations; Automated Rendezvous and Docking; and Robotics.*

In summary, ISS is essential in preparing for crewed missions into the proving ground of cislunar space, and eventually to Mars. It is NASA's plan to first develop and demonstrate the technology capabilities listed above using the ISS as a permanently-crewed testbed prior to deploying these capabilities beyond LEO. This approach is generally much more cost-effective than conducting this research in cislunar space because of the higher costs inherent in operating so far from the Earth.

Question 6b) Have our international partners pledged any funding to help allay the $4 billion per year which NASA is having to spend to maintain the ISS?

Answer 6b):

The success of the ISS program is based on the mutual dependence of all partners and clearly recognizes the unique contributions they each provide to the program. The top-level ISS agreements, the multilateral Intergovernmental Agreement (IGA) and bilateral Memoranda of Understanding (MOU) between NASA and each of the four other partners, provide a framework for cooperation on the ISS Program and for equitably sharing the responsibilities for the common system operations costs among these International Partners. Both the IGA and MOUs state that the ISS partners shall seek to minimize the exchange of funds in the implementation of the ISS Program, including, if they agree, through the use of barter (exchange of goods and services). Please also note that the major European contribution to pay for ISS operations costs for the 2016 to 2020 time frame is the development of the initial Orion service module.

Question 7:

NASA Research and Analysis Program

Please provide documentation about research awards which demonstrate that NASA is open to awarding funds to climate change scientists of varying views, inclusive of all available satellite weather data, as opposed to funding *only* proposals which have the preconceived conclusion that climate change is caused by human activity and can be reversed by human activity.

Answer 7:

A large majority of the research awards made by NASA's Earth Science Division are in response to open calls for proposals solicited through the NASA Science Mission Directorate's annual Research Opportunities in Space and Earth Sciences ("ROSES"; the texts of the 2015 ROSES calls can be found at https://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId={9F1341A9-6D0F-F075-C993-276263B186ED}&path=future.

With the overarching objectives of advancing Earth System Science and developing and testing applications that can provide direct societal benefit, no Earth Science Division solicitation within ROSES 2015 (or prior years) restricted or prohibited proposers from making use of any available satellite data set or information source.

All ROSES selections/awards are made following, and informed by, rigorous peer review that specifically considers explicit criteria stated in the ROSES solicitation. As documented and defined in the NASA Guidebook for Proposers http://www.hq.nasa.gov/office/procurement/nraguidebook/proposer2015.pdf, the main criteria involve intrinsic merit, relevance, and cost realism and reasonableness. With respect to intrinsic merit, peer reviewers are instructed to consider the factors:

(i) Overall scientific or technical merit of the proposal and/or unique and innovative methods, approaches, concepts, or advanced technologies demonstrated by the proposal;

(ii) As documented in the proposal, offeror's capabilities, related experience, facilities, techniques, or unique combination of these which are integral factors for achieving the proposal's objectives;

(iii) The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel critical in achieving the proposal objectives; and

(iv) Evaluation against the state-of-the-art. Review panels are instructed not to compare proposals to each other; all comparative evaluations are conducted by NASA program personnel.
Proposals are never evaluated regarding preconceived notions about the specific results or conclusions that are expected to be reached from the as-yet-uncompleted-at-time-of-award research.

Question 8:

Space Station Cargo Transportation.

Question 8a) With reference to NASA's desire to maintain more than one launch provider, can you explain why all 5 launches currently listed for FY19 are noted as going to one provider? Is that a final decision?

Answer 8a):

NASA was originally planning on purchasing six flights in FY 2019, but is currently re-evaluating its flight plan due to FY 2016 appropriation reductions and current program requirements.

Question 8b) Based on information provided by NASA, as of January 31, 2016, the total value of CRS-1 contracts (as extended by NASA before CRS-2 flights will begin), was $3.039 billion for 20 flights by Space X, and $2.623 billion for 10 flights provided by Orbital Sciences Corporation. Respectively, that is about $150 million per Space X flight and $260 million per Orbital flight. Those costs have gone up since the original contract, despite NASA's willingness to pay for some milestones as far ahead as eight flights ahead of time. The 35,000 pounds taken to the ISS as of January 31, 2016, divided into the total amount paid up to that point, of $3.604 billion, is about $100,000 a pound. (I would note that the Shuttle brought payloads down as a routine matter; thus, I wish to keep the cost of *returning* payloads a separate matter than cargo taken up - unless NASA chooses to say how much per pound and per flight we are paying to bring *back* cargo). It could be assumed that costs might go down (as an average figure) when future flights occur (on which we

have paid some milestones). However, it is also possible that future accidents, loss of cargo, flight delays, or other problems etc. could prevent that average cost from going down. What is NASA doing to hold down the cost of commercial cargo, especially since Shuttle costs, per pound, were lower? (in the range of $25,000 to $30,000 per pound if the Shuttle flew three or more times per year).

Answer 8b):

The Space Shuttle had a very different mission than the commercial cargo and crew suppliers and was not a cost-effective means of long-term ISS resupply. Its ability to lift large amounts of mass to orbit was critical as the ISS was being initially built and outfitted, but it was oversized for the less demanding resupply mission. The competitive nature of the Commercial Resupply Services (CRS) and CRS-2 contracts are one means of holding down the cost of cargo transportation to and from the ISS. There are other factors that may contribute to reduced costs when utilizing a commercial (vs. the use of a Government-owned and –operated) cargo transportation system, including industry sharing in the development costs as opposed to traditional NASA programs where the Agency pays 100 percent of the development costs, and potentially shorter development schedules. In addition, the use of fixed-price contracts and agreements as opposed to cost-plus contracts generally results in lower costs to the Government, provided the requirements are clear and stable.

Question 8c) Why does NASA refuse to make public the cost of individual cargo flights to the ISS? It is a fundamental aspect of competition for a service price to be known, and then met or bested by another competitor's offer. If NASA wants to continue to argue, counter-intuitively, that disclosing costs per flight somehow harm commercial competition, please provide an opinion from your office of legal counsel. Otherwise, I ask that NASA begin disclosing the amount paid for each individual flight to the ISS.

Answer 8c):

CRS contracts provide commercial fixed-price services in a competitive environment. The contracts include not only the total amount awarded to date but also detailed pricing for the many different elements that are part of a task order for a mission. When additional task orders are added to the contract, the contractors are required to compete for the tasks using the detailed pricing in the base contract (reference contract Clause II.A.5). The CRS contract also has a unique "on-ramp" provision that allows additional providers to compete to be added to the contract and then compete for task orders (reference contract Clause II.A.1). Disclosure of the detailed pricing of each contract would impact the contractors' competitive positions and pricing strategies for future task orders. In order to maintain fair competition under the CRS contract, it is essential that NASA protect the commercial pricing aspects under the contracts by marking them Sensitive but Unclassified (SBU).

Question 8d) Is it NASA's position that every flight delay in the commercial cargo program was due to a request by NASA to change the launch date, as opposed to some delays being due to technical or other challenges experienced by the launch provider? If the latter was sometimes the case, please provide to the Committee a list of delayed flights and NASA's noted reason for the delay.

Answer 8d):

CRS flights have experienced launch slips on the part of both NASA and its contractors. Causes for the delays have included:

- *Technical issues with launch vehicle/spacecraft*
- *Production issues/delays due to supplier delays, during manufacturing/testing*
- *Range availability*
- *Launch Day issues – Weather, Debris analysis, DFO analysis, Keep Out Zones (boats)*
- *Manifest conflicts with commercial flights*
- *Updates to Vehicle design*

In cases of delays on the part of the contractors, consideration received by NASA has included:

- *Contractor acceptance of updated/new requirements on contract at no additional cost to NASA*
- *Additional vehicle/operational capability at no additional cost to NASA:*
    - *Powered middeck lockers*
    - *Extended spacecraft duration on-orbit*
    - *Additional early/late stowage of ambient & cold stowage bags*
    - *Non-standard cargo accommodations*
    - *Additional instrumentation*

Question 8e) I have a question about the preparations leading up the launch of the BEAM habitat module. Such modules and payloads could be a significant part of future operations in LEO and beyond. Regarding the clamps which held the BEAM in place, whose decision was it to initiate a pre-launch inspection? Was it initiated by NASA? What were the conclusions regarding how a lack of inspection might have impacted the mission? Finally, what were the engineering conclusions regarding the clamps (design, materials) and what were the conclusions on how to avoid any similar problem with future payloads?

Answer 8e):

The Bigelow Expandable Activity Module (BEAM) Flight Support Equipment (FSE) was designed and tested by SpaceX and is used to hold (and release) the BEAM payload in the SpaceX Dragon trunk. In November 2015, as part of SpaceX-8 trunk closure and walk down, SpaceX and NASA personnel identified corrosion on the BEAM FSE. SpaceX initiated an inspection of the affected latches which required opening the six BEAM FSE latches. While SpaceX was opening the first group of three latches, one of the latch actuators broke in the open position. The other two actuators in operation at that time opened nominally. The other group of three actuators was not operated due to the failure. In flight, had the same failure occurred and the second group of three actuators functioned nominally, the BEAM would have been releasable from the trunk.

A failure analysis conducted by SpaceX and presented to NASA showed that the actuator broke when the latch moved over center. This was demonstrated in the subsequent root-cause investigation and testing. Per the results of the investigation, SpaceX made changes to the design and material construction of the actuators, as well as changes to the operating conditions to which the latches were subjected. SpaceX also added additional review and system-level screening for the latching system. These lessons learned will be applied to future systems.

Question 9:

If I am correct, there have been some opportunities created at NASA for private companies to invest documented amounts of their own money in exchange for matching funds, or close to matching funds, by NASA. For example, on small moon landers, and potential equipment for

future exploration and exploitation of the Moon. My understanding is that one or more commercial companies have met the milestones required to receive matching funds. Has NASA awarded those funds? If not, what are NASA's plans to do so promptly and without harming work necessary to SLS development?

Answer 9:

Through the Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiative, NASA entered into no-funds-exchanged Space Act Agreement (SAA) partnerships with three competitively-selected U.S. private companies in September 2014 to help them develop small robotic lunar lander vehicles and to facilitate the availability of related commercial services for lunar payload space transportation. With these SAAs, which have a nominal term of three years, NASA is providing substantial in-kind contributions including technical expertise, access to test facilities, software, and the loaning of equipment, but is not providing any direct funding to these companies.

NASA's three Lunar CATALYST partners are Astrobotic Technology, Inc; Masten Space Systems, Inc; and Moon Express, Inc. The Lunar CATALYST SAAs include technical and financial milestones, which NASA uses to assess each company's progress in developing their robotic lunar landers and to periodically decide whether to continue providing in-kind contributions to the partnership. However, the SAAs do not provide for the awarding of any NASA funds to the companies, and the SAA milestones are not being used for that purpose.

Additional information about the Lunar CATALYST initiative can be found as follows:

Lunar CATALYST home page: http://www.nasa.gov/lunarcatalyst

Lunar CATALYST Space Act Agreements: http://www.nasa.gov/lunarcatalyst-references

The Honorable Jamie Herrera Beutler
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the NASA FY 2017 Budget Request

Question 1:

There are approximately 70 to 100 commercial satellites being launched every year, and many of these satellites contain sufficient space to host government payloads and government small satellite rideshares. How is NASA taking advantage of this capability in order to cut costs while maintaining U.S. leadership in space exploration?

Answer 1:

Demand for access to space is increasing each year, from both government and commercial sectors. Recognizing this trend, NASA has included language in its recurring Announcements of Opportunity (AOs) and Missions of Opportunity (MOs) that encourages solicitors to consider leveraging commercial launch payloads.

Where feasible, NASA already flies instruments on commercial satellites, sharing the commercial spacecraft's power, propulsion, heat rejection, and communication systems. This substantially reduces our launch costs, and allows us to focus on the development of the science instruments such as the Global-scale Observations of the Limb and Disk (GOLD) and Tropospheric Emissions: Monitoring of Pollution (TEMPO) missions. GOLD will be launched in 2018 as a hosted payload on a commercial satellite in geostationary orbit to examine the response of Earth's upper atmosphere to space weather events that can impact communications, aircraft navigation and spacecraft operations. TEMPO will also be launched as a hosted payload on commercial satellite in geostationary orbit to measure chemical species critical to air quality across the United States once every hour to improve air quality forecasts.

TEMPO was selected through NASA's Earth Venture Instruments (EVI) series of solicitations. The EVI part of NASA's Venture-class program solicits every 18 months for Earth science instruments that will fly on space-borne platforms (commercial satellites, the International Space Station (ISS), etc.). The Global Ecosystem Dynamics Investigation (GEDI) and ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) are two EVIs that will be delivered to the ISS via commercial resupply missions.

Likewise, STMD consistently seeks the most cost-effective approach to reduce launch costs. STMD's approach to access to space is to utilize rideshare or hosted payloads wherever possible. STMD is currently utilizing rideshare for our Green Propellant Infusion Mission (GPIM) project and hosted payload for the Deep Space Atomic Clock (DSAC) project. In addition, all STMD Small Sat project launches to date have used rideshare for access to space. STMD will continue this approach for its future launch needs.

On the topic of small satellite rideshares, especially CubeSats, there is limited immediate need for additional rideshare opportunities. NASA's CubeSat Launch Initiative is currently taking advantage of available capability on NASA launches, as well as other U.S. Government launches and commercial launches. The commercial launches have primarily been ISS cargo resupply missions, however, NASA is working on a mechanism to purchase access to space via commercial launch brokers. These brokers

could provide access to more commercial satellite launches with available capacity. Use of such commercial satellite launches, however, will be considered where the risk tolerance of the NASA rideshare matches the limited Government insight afforded on such arrangements. Lastly, NASA has three nano-class launch providers on contract (Venture Class Launch Services contracts) to provide demonstration launches in 2017 and 2018. If successful, these launch vehicles have the capability to provide access to space for multiple CubeSats and small payloads at a cost that is comparable to rideshares with large primary satellites.
NASA's Launch Services Program (LSP) is also working within the Agency to better enable the utilization of small satellite platforms for the Science and Space Technology Mission Directorates. In support of their access to space, LSP is working to provide assistance to the payload developer to enhance their assurance of an opportunity in the timeframe desired, typically post 2020.

Question 2:

We appreciate NASA's initial efforts to host some science missions like TEMPO and GOLD on commercial satellites. How exactly does NASA plan to take full advantage of the large amount of available commercial payload space in 2017?

Answer 2:

While NASA is considering using commercial capabilities for future missions, it is not possible to alter existing plans to leverage such assets for missions scheduled to launch in 2017. However, NASA is exploring multiple options to leverage the commercial industry's capabilities, from incorporating language into AOs and MOs that would encourage solicitors to explore the use of commercial launches, to selecting commercial contractors for future Venture-Class Launch Services contractors, and through working with industry through hosted payloads.

As stated previously, STMD's approach to access to space is to utilize rideshare or hosted payloads wherever possible, and STMD will continue to utilize this approach for our future launch needs. Likewise, the Science Mission Directorate's FY17 Heliophysics AO Explorer specifically includes language encouraging applicants to consider commercial partners for launch. NASA will select the Heliophysics Explorer opportunities in FY17, but those launches will come at a later time.

In addition, in October 2015, NASA's Launch Services Program selected Firefly Space Systems, Virgin Galactic, and Rocket Lab USA to provide low-cost launches for CubeSats and small satellites under the Venture-Class Launch Services contracts. That and the proposed Small Satellite Constellation Program *have the potential to advance system design, technology and launch/operations approaches for missions employing constellations of small satellites, and foster commercial launch services dedicated to transporting small payloads into orbit and fund competitive grants for small satellite proposals. Lastly, NASA is planning to fly instruments on commercial satellites, sharing the commercial spacecraft's power, propulsion, heat rejection, and communication systems. This substantially reduces our launch costs, and allows us to focus on the development of the science instruments such as GOLD and TEMPO. GOLD will be launched in 2018 to examine the response of Earth's upper atmosphere to space weather events that can impact communications, aircraft navigation and spacecraft operations. TEMPO will measure chemical species critical to air quality across the United States once every hour to improve air quality forecasts.*

Question 3:

Considering NASA has increased their focus on deep space exploration, has NASA considered taking advantage of the frequent commercial launches to GEO for rideshares that would then use electric propulsion to accomplish deep space exploration?

Answer 3:

Regarding NASA's use of rideshare opportunities, please see responses to Questions #002 and 003, above. The potential use of commercial rideshares to GEO for deep-space missions using electric propulsion is to be determined, and will depend in large part on the specifics of the mission, such as power requirements and payload mass.

The Honorable Steven M. Palazzo
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the NASA FY 2017 Budget Request

Question 1:

What is the status of JPL data storage and is JPL considering transferring its data to NCCIPS at Stennis Space Center as part of an overall strategy for NASA consolidated Data?

Answer 1:

NASA (to include JPL) assesses the state of computing systems, applications and storage in response to new requirements and refresh/modernization opportunities. Suitability for cloud is the first option considered, followed by suitability for placement in existing NASA data centers (to include National Center for Critical Information Processing and Storage (NCCIPS)). Factors that affect placement options include type of data, sensitivity level of data, access latency requirement, who needs access to the data and requirement for physical access to hardware. JPL is presently reviewing the requirements of their entire application portfolio in light of efficiency opportunities. All options are still being considered.

Question 2:

What preparations is NASA putting in place now to ensure mission continuity and how can we avoid repeating a cancellation or a delay of SLS when a new President takes office?

Answer 2:

The Administration and a bipartisan bicameral Congress cancelled the Constellation program in 2010 because it was on an unsustainable path -- over-budget, behind-schedule, and according to independent estimates, likely to be incapable of fulfilling one of its intended missions - reaching the International Space Station (ISS) prior to the then-planned retirement of the ISS. The programs that arose – again with support from both the White House and Congress – following the cancellation of Constellation are aimed at being more affordable and sustainable. NASA can avoid repeating the situation that occurred when the current President took office by continuing to execute the plan we have laid out without cost overruns, thus earning the continued support of the American people.

Question 3:

If the Agency's/Administration's request is sufficient, then why was the EM-1 date delayed by 1 year based mostly on the funding level requested by the Administration vs. the appropriations?

Answer 3:

The EM-1 date was not delayed based on the funding level requested by the Administration. The FY2017 Budget Request fully funded the Agency Baseline Commitment for the SLS and EGS, which at the time of its development, supported a launch capability readiness date of November 2018 at 70 percent and 80

percent Joint Confidence Level (JCL), respectively, to the EM-1 launch readiness date. While NASA has consistently been appropriated higher levels than this amount, because of changes in program schedule and funding needs, this amount continues to support a November 2018 readiness date. The Space Launch System (SLS), Orion, and Exploration Ground Systems (EGS) are progressing along an efficient path for completion of detailed design and for manufacturing, assembly and testing. NASA has identified an Agency Baseline Commitment for Orion for the first crewed launch as the Exploration Mission-2 (EM-2) readiness date in 2023 at a 70 percent JCL.

Question 4:

Again, if the schedule slip is due in part to the inadequate request level, then why does NASA continue to ask for less every Fiscal Year for SLS and Orion than was previously planned for in the prior Fiscal Year's out-year request?

Answer 4:

The schedule slip is in no part due to an inadequate request level. Consistent with prior years, the President's FY 2017 Budget Request for SLS/Orion fully funds the Agency Baseline Commitment for SLS/Orion, as established at their respective KDP-C events. This amount is also consistent with the notional outyear assumptions in previous requests... Both programs have previously also been funded at levels greater than the NASA's requests; as a result, any schedule adjustment are due to changing technical and funding requirements.

Question 5:

Since the levels requested by the Administration to date were a contributing factor in the launch date slip of EM-1, do we need to be concerned with insufficient levels in the FY17 request impacting scheduled engine tests at Stennis Space Center this year or the scheduled core-stage test at Stennis Space Center in 2017?

Answer 5:

The President's Budget levels have not been a contributing factor in any launch date slips. NASA's funding requests have fully supported the Agency Baseline Commitments and additionally, NASA has consistently received appropriations greater than these amounts. As a result, any schedule slips are a result of changing technical and cost requirements.

Please see below an outline of planned worked to be performed at Stennis Space Center in FY 2016 and FY 2017.

Stennis Space Center – FY 2016 Plans

- *Perform five tests of RS-25D engine to support SLS.*
- *Continue developmental and flight certification testing of commercial engine systems on reimbursable basis.*
- *Perform U.S. Air Force LOX/RP development testing supporting the Air Force-funded Hydrocarbon Boost program.*
- *Complete refurbishment of B-2 test stand to prepare for SLS core stage testing.*

- *Complete replacement of E Test Complex data acquisition system to support test of sub-scale and component assemblies and engines.*

Stennis Space Center – FY 2017 Plans

- *Complete development of the special test equipment required to support the SLS Core Stage.*
- *Activate B-2 test stand for SLS Core Stage testing.*
- *Begin testing SLS Core Stage on the newly refurbished B-2 test stand.*
- *Perform engine testing for Aerojet Rocketdyne RS-68 engine, Aerojet Rocketdyne AR-1 engine, SpaceX and other commercial engine developers.*
- *Perform component testing for the U.S. Air Force LOX/RP test program.*
- *Perform facility modifications to the A-1 test stand necessary to support future SLS RS-25E engine development.*

Question 6:

Has NASA and the Administration taken the time to assess the impact to companies, particular small and medium sized businesses, and their workforce based on the indecision, the stops and starts, the discrepancies in funding that delay program planning and push milestones and launch dates to the right?

Answer 6:

As the question notes, the irregular appropriations cycle, government shut-downs, and sequestration create enormous difficulty for NASA to adequately plan for and manage programs. The annual program execution is planned to the appropriated levels, in which the workforce costs must fit. Orion's development phase runs through the EM-2 launch and therefore there is significant non-EM-1 work also proceeding in parallel leading up to EM-2, such as the Ascent Abort-2 flight test. As engineers and technicians move from design to production, work on various elements of SLS will be adjusted to match the progress being made to build the rocket. NASA's contractors size their workforce as they determine necessary for performance of their contracts. When tasks related to Exploration Mission-1 (EM-1) are completed within SLS and Orion, the workforce can progress to Exploration Mission-2 (EM-2).

Material for the Record
March 15, 2016, Hearing on NASA's FY 2017 Budget Request
before the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies

Material for the record by Mrs. Roby, regarding launch date for EM-2 (page 51-53)

Question 1:

Could NASA launch EM-2 in 2021 if Congress were to increase the level of funding for the Space Launch System (SLS) and Orion?

Answer 1:

In 2015, the Agency conducted a Key Decision Point review of the Orion program, establishing an Agency baseline commitment level for Orion that supports a 2023 launch readiness date for EM-2 at a 70 percent Joint Confidence Level. The Space Launch System (SLS) and Exploration Ground Systems (EGS) launch readiness dates and funding requirements to support EM-2 will be provided in response to the Congressional reporting requirement on this topic. Currently, NASA continues to hold the Orion program to a schedule consistent with an EM-2 launch readiness date of August 2021, per the internal Management Agreement for the Program. The Agency baseline commitment date for Orion was developed after considering multiple funding profiles and the likelihood of meeting various launch planning dates at those levels. Generally speaking, additional funding would increase the likelihood of launching EM-2 prior to the April 2023; however, total funding is only one factor for NASA and its contractors in meeting schedule and cost targets. The launch planning date for EM-2 will be updated after funding availability is better understood and contract activity is finalized.

Material for the Record
March 15, 2016, Hearing on NASA's FY 2017 Budget Request
before the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies

Material for the record by Mr. Jolly, regarding funding for EUS on pages 30-31

Question 1:

Will NASA be able to fly the Exploration Upper Stage (EUS) on Exploration Mission-2 (EM-2) given the President's Budget Request for FY 2017?

Answer 1:

Under the President's Budget Request for FY 2017, Exploration Mission-2 (EM-2) would launch with SLS Block 1 using the Interim Cryogenic Propulsion Stage. The FY 2016 Appropriations Act directs NASA to develop the EUS for the second joint mission of the Agency's Space Launch System and Orion spacecraft. With this direction, and the funding provided in the FY 2016 Appropriation, the SLS Program will mature the EUS to the level of Preliminary Design Review (PDR), to be held near the end of calendar year 2016. This spring, NASA issued a sole-source request for proposal (RFP) to Boeing to determine the development and hardware costs associated with the EUS. NASA is also pursuing a sole-source request for proposal (RFP) to Aerojet Rocketdyne to support production of the first flight set of RL10 upper stage engines, the associated integration, and required human rating information for the EUS. Other contracting activity in support of EUS will likely follow later this year for the Universal Stage Adapter (USA). NASA will continue to assess implementation of EUS as we progress through the developmental cycle.

Material for the record by Mr. Jolly, regarding savings from commercial providers on page 65

Question 2:

Has NASA achieved savings through using commercial providers for cargo and crew transportation?

Answer 2:

Yes. The seat price of Commercial Crew transportation, using the contractual prices established in the CCtCap contracts for all 12 potential missions, is equivalent to $58 million per seat. The currently contracted seat price for Soyuz for 2018 is approximately $82 million per seat. The Commercial Cargo program cost approximately $780 million in development funds, but also resulted in the development of two new rockets that have won back a large fraction of the commercial space launch market for the United States and have helped to reduce the cost of space launch for NASA and defense missions. The Commercial Crew Program is not yet complete. However, it is anticipated that, when both Commercial Crew partners, SpaceX and Boeing, have completed their

systems, the United States will have developed two new, independent, human space transportation systems for a total cost, including all prior phases, of less than $6 billion to the U.S. taxpayer. NASA's experience developing and operating comparable systems using a traditional approach indicates that they would have cost significantly more. The Commercial Cargo and Crew program is expected to cost about $2 billion/year to operate. While not a direct comparison because of its additional capabilities, the Space Shuttle cost $5-$6 billion per year (in 2016 dollars).

The Honorable Michael M. Honda
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the NASA FY 2017 Budget Request

Question 1:

I was interested in the recent announcement of the Earth Venture instrument program and the use of CubeSats for Earth Science. What role do you see for CubeSats and small satellites in the Science Mission Directorate at NASA? How is NASA partnering with commercial partners to take advantage of this emerging field of small satellite producers?

Answer 1:

NASA's Science Mission Directorate has begun to develop small spacecraft to deliver high-quality science quickly and cost effectively while allowing a larger group of scientists, engineers, technicians, and students to gain hands-on experience in the demanding practice of designing and flying spacecraft. Small spacecraft are also excellent platforms to demonstrate the feasibility of new technologies, and provide educational opportunities for students from high schools and universities.

Nowhere is this innovation in small spacecraft more applicable than in our Earth science missions. Earth is a complex, dynamic planet that must be studied as a system, requiring global observations continuously over the long-term. Collecting temperature, wind speed, salinity, biomass, and geological data, for instance, with high spatial and temporal resolution across the entire globe requires a large fleet of airborne, surface, and spaceborne instruments. Small missions are increasing the breadth of simultaneous, high-quality measurements as well as ensuring the continuity of selected key data sets, augmenting data that is feeding high-resolution models to provide an ever more detailed view of our world.

Because of their lower cost, it is feasible to conduct some missions using swarms of small Earth-orbiting satellites working in concert to simultaneously collect data over large areas. The Cyclone Global Navigation Satellite System (CYGNSS), scheduled to launch in 2016, is a constellation of eight small satellites that will make frequent measurements of winds in the eye-walls of rapidly developing tropical cyclones and hurricanes using reflected GPS signals from the ocean surface. The Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) investigation is a mission composed of twelve instrumented CubeSats that will frequently measure atmospheric profiles of temperature, rain, and humidity in tropical and mid-latitude storms as frequently as every 21 minutes. TROPICS was selected in March 2016 and is planned to launch in 2019.

While Earth science lends itself well to using small-format satellites, NASA also is using them to explore our Sun, its planets, and the rest of the universe. Mars Cube One (MarCO) – the world's first interplanetary CubeSat mission – will be launched with NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission to Mars in 2018. After launch, MarCO's two CubeSats will fly independently to Mars where they will be positioned to observe the descent of InSight's lander. The CubeSats will relay lander data promptly back to Earth, demonstrating two-way X-band communications using a softball-size radio. The CubeSat to study Solar Particles (CuSP) will measure dynamic particles and magnetic fields emanating from the Sun, and will be one of the first CubeSats to be launched on the first Space Launch System mission, EM-1, in late 2018.

In October 2015, NASA selected Firefly Space Systems, Virgin Galactic, and RocketLab USA to provide low-cost launches for CubeSats and small satellites under our Venture-Class Launch Services contracts. We have also proposed the Small Satellite Constellation program to advance system design, technology and launch/operations approaches for missions employing constellations of small satellites. This would foster commercial launch services dedicated to transporting small payloads into orbit and fund competitive grants for small satellite proposals. If appropriated, it would likely result in a ($20M total) solicitation to industry for data delivery from focused small-satellite constellations likely in the fields of land imaging or GPS Radio Occultation atmospheric sounding. Multiple selections are possible.

Another way we are working with industry is through hosted payloads. NASA flies instruments on commercial satellites, sharing the commercial spacecraft's power, propulsion, heat rejection, and communication systems. This substantially reduces our launch costs, and allows us to focus on the development of the science instruments such as the Global-scale Observations of the Limb and Disk (GOLD) and Tropospheric Emissions: Monitoring of Pollution (TEMPO) missions. GOLD will be launched in 2018 to examine the response of Earth's upper atmosphere to space weather events that can impact communications, aircraft navigation and spacecraft operations. TEMPO will measure chemical species critical to air quality across the United States once every hour to improve air quality forecasts.

Question 2:

How is NASA taking advantage of commercial and international interest in lunar exploration? How is NASA partnering with commercial companies to develop and participate in small scale lunar robotic science missions? What is the current status of lunar prospecting programs that will enable a better understanding of the subsurface lunar geology, particularly in-situ water resources?

Answer 2:

Along with our commercial and international partners, NASA has a continued interest in lunar exploration and is working to continue scientific investigations of our celestial neighbor. A recent example of this is the selection of the Lunar Polar Hydrogen Mapper (LunaH-Map) through NASA's Small Innovative Missions for Planetary Exploration (SIMPLEx) program. LunaH-Map is a small satellite designed by Arizona State University to sense the presence of hydrogen in craters and other areas on the moon using a neutron spectrometer. When completed, it will be one of 13 CubeSats to launch on the first integrated flight of NASA's Space Launch System (SLS) and Orion spacecraft in 2018. Upon arrival, the spacecraft will produce the most detailed map to date of the moon's water deposits, unveiling new details about the depth and distribution of the ice that has been identified from previous missions. Confirming and mapping those deposits in detail will help NASA understand how much water might be available and will help inform NASA's strategy for sending humans farther into the solar system.

The Advanced Exploration Systems (AES) Program in NASA's Human Exploration and Operations Mission Directorate is also supporting CubeSats that will be involved in lunar research. Lunar Flashlight is another CubeSat that will be launched on the first mission of the SLS. Lunar Flashlight will fly over permanently shadowed craters at the lunar poles and illuminate them with lasers. The reflected laser light will be measured by an onboard spectrometer to detect the presence of water ice and other volatiles on the crater floors. A third CubeSat called Lunar IceCube is being developed in partnership with Morehead State University to search for ice deposits from lunar orbit. All three of these CubeSats are performing complementary measurements that will help to address key strategic knowledge gaps related to the abundance and distribution of volatiles.

In addition, NASA's Lunar Reconnaissance Orbiter (LRO) shares data with the public through the Planetary Data System (PDS). Data is uploaded on a 3-month cadence and the public can suggest future targets for high-resolution imagery (which are prioritized by scientific objective or completed on a non-interference basis). Most recently, LRO has been acquiring imaging and topographic data for candidate Chandrayaan-2 landing sites, making these data available to the Indian Space Research Organisation (ISRO) through PDS. The PDS data has also been utilized by the Google Lunar X-Prize foundation for locating potential landing sites.

NASA's Resource Prospector, which is in formulation in AES, aims to support the first mining expedition on another world. NASA's efforts are focused on developing a suite of instruments to locate resources in regolith, particularly in the lunar polar regions. NASA is pursuing international and commercial partners who would provide a rover- designed to drill for subsurface samples of the lunar regolith, and directly characterize the abundance of any volatiles that the samples may contain. Building on the findings of the Lunar Crater Observation and Sensing Satellite (LCROSS) and LRO missions that proved the existence of water on the moon, Resource Prospector would take the next step and harvest those resources.
NASA's Lunar CATALYST initiative in AES is currently supporting three companies through unfunded Space Act Agreements to develop lunar landing capabilities. The companies are Astrobotic Technologies, Moon Express, and Masten Space Systems. NASA is providing engineering expertise, hardware and software, and test facilities to these companies. Initial flights of commercial lunar landers may begin as early as 2018, and as a result one or more of these companies will be able to market lunar payload delivery services for small instruments and technology demonstrations.

Question 3:

Has NASA's Science Mission Directorate considered potentially forming and promoting public-private partnerships to execute significant scientific space missions that include substantial private financial backing, leverage government investments in technology, data processing and data analysis, and bear directly on the scientific priorities articulated in the National Research Council's decadal surveys?

Answer 3:

NASA's Science Mission Directorate considers public-private partnerships for significant space missions and actively pursues credible concepts that help achieve scientific priorities articulated in decadal surveys and national policies. For example, in January 2016, NASA signed a Space Act Agreement with the BoldlyGo non-profit institute to explore a dust sample return mission from the Martian atmosphere. BoldlyGo intends to design and conduct the mission, using non-NASA funds for the entire mission including launch and return. Upon determination that the mission would provide sufficient data value, NASA intends to provide scientific and technical consulting, and guidance about planetary protection policies, limited to that which can be included as additional duties as assigned without requiring additional staffing. In addition, to a level that can be accommodated within existing and planned mission sets, NASA would provide communication, scheduling, mission design, and navigation support services to supplement the mission's operations, command, telemetry, and tracking. In return, NASA will receive at least 10 percent of the returned Martian dust samples and data on the physical conditions encountered during the transit through the Martian atmosphere. NASA also reserves the right to provide additional instrumentation to increase the science scope of the proposed mission.

Question 4:

As part of the discussion with Dr. Elachi and Dr. Lunine at an Ocean Worlds Hearing, Chairman Culberson and I heard that searching for signs of life and searching for planetary habitability for life are two different things. We heard that a planned orbiter and potential lander will analyze habitability of Europa, which is quite different from detecting life or the signs of life.

- **Is searching for the signs of life a goal of the Europa Clipper mission?**
- **What would be required to actually search for life (and not just habitability) with the orbiter? Is NASA looking at secondary mission concepts for Europa Clipper that would explicitly search for signatures of life – perhaps through the "handed-ness of amino acids"?**
- **At the Ocean Worlds hearing, we heard that flying through a plume could enable instruments to look for life. Unlike on Enceladus, plumes on Europa seem to be fairly rare. NASA missions in the past have used impactors to create artificial plumes for studying – is this an option for Europa?**

Answer 4:

The goal of NASA's planned Europa mission is to conduct detailed reconnaissance of Jupiter's moon Europa and investigate whether the icy moon could harbor conditions suitable for life. The instruments selected for the currently planned mission to Europa are designed to determine habitability, which is the first and necessary step toward life detection. However, some of the selected instruments also have the ability to detect biosignatures, which are materials that provide evidence that life could be present. NASA recently tasked the instrument teams to consider modifications which would further enhance the selected payload's life detection capabilities.

Earlier in FY 2016, NASA assessed the potential for secondary payloads that may enhance science return from the mission, particularly for life detection. After reviewing the concepts, NASA determined that the gain in science was only low to moderate but would create additional cost and complexity not justified by the science gain. Concerns were also raised about the technical readiness of some of the instruments for these secondary payloads.

NASA also recently conducted a study for using small spacecraft to impact Europa and create short-lived debris plumes for scientific investigation. The study determined that there were significant uncertainties about the amount and quality of material that would be lofted. It was also found that such artificially created impact plumes would be far smaller than the naturally occurring geysers that are present on Enceladus and that we believe are present on Europa. Based on these findings, NASA determined that an artificial plume generator is not a feasible option for the Europa mission. However, the Surface Dust Mass Analyzer instrument on the flyby spacecraft will analyze any such material that is naturally blown off the surface.

Question 5:

To what extent would the absence of a lander in the initial Europa mission reduce the amount of science discovery that would be possible in such an initial Europa mission? To what extent would the inclusion of a lander, as part of NASA's initial planetary science mission to Europa, increase the risk of the mission being unable to successfully land on Europa's surface? For uncrewed science missions, has NASA previously attempted to (1) simultaneously launch both an orbiter and a separate lander in the same payload and (2) kept both of them simultaneously operating once the

planetary destination was reached? In what ways could the uniqueness of such an initial Europa mission increase its overall mission risk? To what extent would mission risks and total life cycle cost and schedule be reduced by making the initial Europa mission an orbiter without a lander?

Answer 5:

The absence of a lander in the initial Europa mission would in no way reduce the amount of science discovery from the orbiter mission. In fact, the lander mission is dependent on the orbiter mission to locate a safe and scientifically interesting landing site. Given the lack of knowledge of the surface conditions of Europa, landing prior to the reconnaissance to be performed by the orbiter mission cannot be justified. NASA completed a study of lander concepts that included one spacecraft to carry both the flyby and the lander components and operate them simultaneously. An Independent Review was held and the findings showed no advantage in this concept as well as excessive cost, risk and complexity growth. Ongoing lander concept studies include analyzing options for separate or co-manifested orbiter and lander missions.

Question 6:

What is the current estimate of the total development and lifecycle cost in dollars for a Europa mission? Please include the development and lifecycle cost estimate (in dollars) for a possible mission architecture of (1) an orbiter, (2) an orbiter with a lander abiding by planetary protection protocol, (3) an orbiter with an alternative secondary mission component such as an impactor.

Answer 6:

(1) NASA's FY 2017 budget request continues formulation for the flyby mission to Jupiter's moon, Europa, under the newly established Outer Planets and Ocean Worlds Program. The multiple flyby mission entered Phase A formulation in June 2015 and is anticipated to enter Phase B in early 2017. Costs and schedule for the current Europa mission design are not firm, as the mission is still in formulation and NASA does not commit to costs and schedules until KDP-C. The total cost of the Europa flyby mission is currently estimated at $3-4B, including launch vehicle.

(2) Ongoing Europa studies include analyzing options for separate or co-manifested flyby and lander missions.

(3) NASA has assessed the possibility of secondary payloads that may enhance science return from the mission. Given the potential for a secondary payload to add cost and complexity to the flyby mission with only a low to moderate science value, NASA has determined such additions, including an artificial plume generator, would not be feasible from both a technical and budget standpoint.

Question 7:

What is the process for determining how a mission like the Europa mission is undertaken in terms of selecting mission plans, selecting instruments, choosing NASA centers and making sure that all of NASA's expertise across the country are involved?

Answer 7:

Strategic decisions for future missions and scientific pursuits within NASA's Science Mission Directorate (SMD) are driven by priorities recommended in the National Academy of Sciences (NAS) decadal surveys, national needs, and guided by a commitment to preserve a balanced program across the four major science disciplines (Astrophysics, Earth Science, Heliophysics and Planetary Science). Investment choices in SMD are based on open competition and scientific peer review as the primary means for establishing merit for selection of research and flight projects. For competed space missions, NASA solicits complete scientific investigations involving new space missions via Announcements of Opportunity (AO); teams of industry, academia, or NASA centers propose to these AOs. For strategic missions (such as the Europa mission), NASA solicits scientific instruments via AOs, allowing competition and scientific peer review to guide the selection of the best science proposals. Strategic missions are defined based on NAS decadal surveys and national policy direction. In each case, NASA evaluates each proposal in response to an AO on the basis of the following criteria:

- *Scientific merit of the proposed investigation;*
- *Scientific implementation merit and feasibility of the proposed investigation; and*
- *Technical, management, and cost (TMC) feasibility of the proposed mission implementation, including cost risk.*

Occasionally, NASA will direct the assignment of a sensor or instrument to a specific NASA Center.

Question 8:

I was pleased that the Science Mission Directorate has recently recognized other Water Worlds (including Enceladus) with potentially interesting astrobiology and opened a New Frontiers competition to look into exploring these worlds. Please provide an update on these proposed programs to visit Enceladus, Titan, Triton, and the other Ocean Worlds

Answer 8:

At this time, NASA is working to develop an announcement of opportunity (AO) for the next New Frontiers mission and therefore, has not yet selected any proposed missions. The announcement will add Ocean Worlds as a new destination to the mission list, specifically soliciting missions focused on the search for signs of extant life and/or characterizing the potential habitability of Titan or Enceladus. NASA expects to release within the next few weeks an announcement about the science objectives for all destinations on the list, followed by a draft AO for New Frontiers in the summer of 2016. The final AO is expected to be released in January 2017.

Question 9:

The NASA Technology Transfer Program ensures that NASA technologies transform into commercial products and services that provide the greatest benefit to the United States by tracking, analyzing and reporting NASA's technology investments and progress, as well as managing NASA's patent licenses and software releases. There are many examples of the benefits of having a robust and effective Technology Transfer Program yet NASA funding for the program within Space Technology has fallen dramatically over the past decade. What is NASA doing to maintain and strengthen this critical Agency function?

Answer 9:

The NASA Technology Transfer Program has been coordinating the work of the NASA field centers to enable more efficient operations and ensure that more NASA technologies are infused into America's private sector. NASA also has standardized, streamlined, and automated processes and created tools that give the outside world a seamless and integrated interface with the agency. NASA has leveraged our technology portfolio's marketing collateral value through partnerships with other organizations. The results of these efforts are demonstrated in the increased rate of technologies being transferred to American industry. In four years, despite a decreasing budget, NASA has managed a 250 percent increase in annual patent licensing and a 100 percent increase in software releases. This past fiscal year, NASA licensed 74 technologies to businesses and other organizations and fulfilled more than 2,100 requests for software. To continue and build on the Technology Transfer Program's momentum and progress, NASA has proposed increasing the funding level for Technology Transfer and plans to continue the increased funding in FY 2017, which is reflected in the President's FY 2017 budget request.

Below is the Technology Transfer Funding history since its transfer to OCT/STMD.

- *FY 2012 $21.2M*
- *FY 2013 $19.8M*
- *FY 2014 $17.5M*
- *FY 2015 $17.6M*
- *FY 2016 $18.1M*
- *FY 2017 (President's Budget Request) $20.0M*

Material for the Record
March 15, 2016, Hearing on NASA's FY 2017 Budget Request
before the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies

Material for the record by Congressman Honda, regarding astronaut applicants on page 9

Question 1:

Please provide basic demographic information on the most recent set of astronaut applicants.

Answer 1:

Please see demographic data, below.

- Male Applicants: 58%
- Female Applicants: 18%
- Did Not Disclose Gender: 24%

Race/National Origin (RNO)

RNO	RNO Totals %
African American	**2.60%**
Asian	**5.20%**
Caucasian	**55.90%**
Hispanic	**1.70%**
Native American	**0.20%**
Pacific Islander	**0.10%**
MULTI-RACIAL	**9.50%**
RNO NOT DISCLOSED	**24.80%**
	100.00%

Material for the record by Congressman Honda, regarding geysers page 61

Question 2:

A lot of discussions around that and when we did talk about geysers, it was clear that there were natural-occurring geysers and then there is a - we can impose or create geysers through impacts. Is that something that --

Answer 2:

Any impact of Europa will loft material off the surface and into space. Even the very tiny micrometeoroids that constantly bombard Europa's surface eject small amounts of material off the

surface and dozens of miles into space. In fact, the Surface Dust Mass Analyzer instrument on the flyby spacecraft will analyze such material that is naturally blown off the surface. In addition, NASA recently conducted a study for using small spacecraft to impact Europa and create short-lived debris plumes. The study determined that there were significant uncertainties about the amount and quality of material that would be lofted. It was also found that such artificially created impact plumes would be far smaller than the naturally occurring geysers that are present on Enceladus and that we believe are present on Europa.

Material for the record by Congressman Honda, regarding Technology Transfer Program on page 63

Question 3:

Can you talk a little bit about Technology Transfer Program and explain to me the funding levels that have occurred over time; will this decline or remain the same? It appears that is declining, and it seems like this is something that we really should be paying attention to, to make sure that we really do, plus-up with the kinds of investments that we make in research and development at NASA.

Answer 3:

Below is the Technology Transfer Funding history since its transfer to OCT/STMD.

- FY 2012 $21.2M
- FY 2013 $19.8M
- FY 2014 $17.5M
- FY 2015 $17.6M
- FY 2016 $18.1M
- FY 2017 (President's Budget Request) $20.0M

The NASA Technology Transfer Program has been coordinating the work of the NASA field centers to enable more efficient operations and ensure that more NASA technologies make their way into America's private sector. NASA also has standardized, streamlined and automated processes and created tools that give the outside world a seamless and integrated interface with NASA. NASA has leveraged our technology portfolio's marketing collateral value through partnerships with other organizations. The results of these efforts are demonstrated in the growing rate of technology being transferred to American industry. In four years, NASA has managed a 250 percent increase in annual patent licensing and a 100 percent increase in software releases. This past fiscal year, NASA licensed 74 technologies to businesses and other organizations and fulfilled more than 2,100 requests for software. To continue and build on the Technology Transfer Program's momentum and progress, NASA is increasing the funding level for Technology Transfer and plans to continue the increased funding in FY 2017, which is reflected in the President's FY 2017 budget request.

The Honorable Derek Kilmer
Subcommittee on Commerce, Justice, Science, and Related Agencies
Questions for the Record
Hearing on the NASA FY 2017 Budget Request

Question 1:

I am a strong advocate of looking for mutually beneficial opportunities for peaceful technological and scientific collaboration with our partners in Israel. In October of last year, NASA and the Israel Space Agency took steps to renew and strengthen their longstanding partnership, which has endured for over thirty years. We have been through a lot together in space. We rejoiced together in the success of the Mars Curiosity rover, to which Israel supplied vital components, and mourned together after the loss of the Space Shuttle Columbia. What new opportunities resulting from our partnership with the Israel Space Agency do you see on the horizon? How can we leverage our partnership to advance U.S. scientific and exploration goals in space?

Answer 1:

NASA and the Israel Space Agency (ISA) have a strong partnership and both agencies are committed to its continued and long-term success. In October 2015, NASA and ISA signed a framework agreement to enable cooperation in a number of areas. These areas include aeronautics, space exploration and operations, science, and other areas of mutual interest. With ISA's recent appointment of a new Director General, NASA anticipates that the Agency and ISA will continue the dialogue on prospective cooperation in space science, exploration and Earth science.

Question 2:

Earth science is one of NASA's key mission areas. Representing a substantial submarine force homeported at Naval Base Kitsap, I am sensitive to the importance of earth science to our national security. America's submarine force needs to know the salinity and temperature of the sea and the flow of underwater currents to maintain its stealth and be successful in its mission. I have been informed that the Navy routinely relies on earth science data from NASA and NOAA. I am interested to hear your thoughts, as a Marine, about the importance of this mission for NASA and the adequacy of funds to meet the needs of sailors who are projecting power forward?

Answer 2:

By deliberate design, the nation's investment in NASA's Earth- and ocean-observing research satellite systems is routinely and continuously leveraged to provide critical information that supports our fighting forces as well as civilians. NASA satellites make global, accurate, high-resolution, all-weather (clear sky and clouds, day and night) measurements of key environmental quantities in and over the vast global oceans. Instruments on NASA satellites – including some on the International Space Station – monitor, among other variables:

- *ocean surface wind speed and direction, tracking storms and precisely measuring the winds that drive upper-level ocean currents on all scales;*
- *wave heights;*

- *large-scale ocean currents;*
- *sea-surface temperatures with high accuracy, precision, resolution, and coverage;*
- *the ocean's mesoscale eddy field (of critical importance for submarine detection and evasion);*
- *sea-surface salinity, also with unprecedented accuracy, precision, resolution, and coverage;*
- *precipitation (which, with wave and wind conditions, contributes to upper ocean "noise" that degrades sonar measurements); and*
- *sea-ice extent and thickness in polar regions.*

In addition to being used by government and private sectors for scientific research and applications such as efficient ship routing, all of the data from NASA's ocean-observing satellites and instruments are transmitted to the ground in near-real-time, where the measurements are used routinely for improving the accuracies of tactical short- and medium-term weather forecasts by operational agencies such as the civilian NOAA/National Weather Service, the National Hurricane Center, the civil/DoD Joint Typhoon Warning Center, and the military Fleet Numerical Meteorology and Oceanography Center. (Over land, measurements of precipitation, soil moisture, dust, winds, aerosols, and clouds from NASA satellite instruments are similarly used operationally for tactical trafficability, visibility, and dust forecasts for ground troops and aviators, as well as contributing to more accurate regional and global weather forecasts.)

On a more strategic level, one of the greatest threats to national security is climate change, which impacts sea levels, coastal communities, the frequency and intensities of extreme weather events and storms (especially over the oceans), sovereignty, the arctic polar icecap, and shipping lanes to name a few examples directly tied to naval operations. Looking more inward, climate change has direct economic impacts driven by such factors as warmer temperatures, seasonal change, extreme weather and severe droughts. Studying the science behind climate change is essential to predicting future global issues and informing policy on national security. The President's FY2017 budget request maintains a strong Earth Science program for the nation addressing some of the most critical questions we have about how and why Earth's climate and environment is changing. Whether obtained from a research agency like NASA or daily weather monitoring/forecasting agencies like the civilian NOAA or the military Fleet Numerical Meteorology and Oceanography Center, all branches of the US armed forces including the Navy and Coast Guard address national security by using climate data to aid in their planning, anticipation of, and response to changing situations across the world.

WEDNESDAY, MARCH 16, 2016.

NATIONAL SCIENCE FOUNDATION

WITNESS

HON. FRANCE A. CÓRDOVA, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. CULBERSON. The Commerce, Justice, Science Appropriations Subcommittee will come to order. We are pleased to have with us this morning the Director of the National Science Foundation, Dr. France Córdova. And we thank you very much for your service to the country, Dr. Córdova. We have on this committee a long history of strong bipartisan support for the work that the National Science Foundation does and a commitment to make sure the United States maintains its leadership in scientific research and the role that you play is absolutely essential.

We have a very difficult budget year but we are going to continue to do everything that we can to ensure that you and the scientists that work under the peer review grant process that you oversee have the resources that you need to maintain American leadership in scientific research.

We have before us the President's 2017 budget request, which is about $7.6 billion, an increase of $101 million, or about 1 percent above the current fiscal year. And unfortunately the President's budget request includes about $400 million in new unauthorized mandatory funding from a variety of sources that are all just not going to happen. It is a difficulty that every agency that is presenting their budgets this year to the Appropriations Committee face. You are not alone in this. And I know this budget did not come from you personally. I understand that you made recommendations to the Office of Management and Budget. They include these extraneous recommendations, the taxes and fee increases and speculative sources of funding for the future that are just simply not going to happen. We had this dilemma with the Administrator of NASA. And we are devoted to NASA and the National Science Foundation. But these mandatory funding increases are simply not going to happen. And it makes it more difficult for the Appropriations Committee to do our work, to support you and help you in an extraordinarily difficult budget year. It complicates things tremendously when the President submits a budget request both for NASA and the National Science Foundation that he knows will never get enacted, that includes funding sources that are utterly unrealistic and improbable. It puts us in an even deeper hole than we are. But we are going to work together. Mr. Honda and I are both, the full subcommittee is committed to work with you and to help you do what you need to do.

I know Mr. Honda joins me in congratulating you and your partners at the Jet Propulsion Laboratory and the Massachusetts Institute of Technology and others on the extraordinary discovery that you have made recently using the Laser Interferometer Gravitational-Wave Observatory in confirming the existence of gravitational waves that I know some of the scientists were up here a couple of weeks ago and my day was just berserk. I am sorry I did not get a chance to meet them personally. But I am looking forward to visiting with them, as I know Mr. Honda is, to hear firsthand about their discovery. We would love to hear you talk a little bit about that today, if you could. In fact, this is something that was theorized by Albert Einstein about a hundred years ago.

In fact the Laser Interferometer Gravitational-Wave Observatory was a project that was originally supported by this subcommittee under the leadership of Chairman Livingston and Chairman Rogers. And that work took many years. It requires an investment that the seed has to be planted in the ground and nurtured and carefully supported by subsequent Congresses and subsequent Directors of the National Science Foundation to make sure that they come to fruition. And we will certainly do our part, as I know you will as well. We really do congratulate you and all of the researchers who are involved in this extraordinary achievement.

The National Science Foundation's annual budget represents about 60 percent of the total Federal budget for basic research conducted at U.S. colleges and universities, excluding medical research that is supported by the National Institutes of Health. In many fields the National Science Foundation is the primary source of Federal academic support for scientific research. So we want to add while we wholeheartedly support research and the sciences we of course also need to be exceptionally good stewards of our constituents' hard earned tax dollars and be very careful and frugal about how they are spent. And we are just delighted to have you here with us today and thank you very much for your service. And I want to recognize Mr. Honda for any remarks he would like to make. Thank you.

Mr. HONDA. Thank you, Mr. Chairman. And good morning, Dr. Córdova, and thank you for being here today. So I am really looking forward to your testimony and learning more about the great programs that NSF has. As a former science teacher and a representative for Silicon Valley, I know well the tremendous value that NSF has for us. And NSF is known as the great fundamental research venture capitalist for the United States. So NSF supports ideas and research that is on the cutting edge and often has no clear application beyond the pursuit of scientific knowledge.

By investing in a broad range of ideas you never know which ones are going to come up and pan out and end up having enormous implications for society and impact to our economy, such as the recent discovery probably changed a lot of rules in physics.

These breakthroughs then trigger commercial investments in R&D to develop an idea and bring it to market. This one-two punch of NSF investment in the fundamental research followed by commercial R&D investments in ideas when they have potential market implications is a proven recipe for success.

If it were not for the broad initial investment in the fundamental research by NSF, then this innovative cycle from lab to market would grind to a halt. The NSF is directly fueling our future innovative economy and is making sure that the next breakthrough technologies that lead to the next Silicon Valleys happen right here in the United States.

The thing about fundamental research is you never know which idea is going to end up becoming the next 3D printer or the next silicon wafer or the next new fuel cell or the next detected gravity waves. This is why the NSF needs the freedom to invest across all of the sciences without interference. It is critical that politics not be allowed to insert itself into the process and deem that some sciences are not in the national interest and therefore we will not invest in them. All science is in the national interest and all science contributes to an innovative environment from which the next breakthroughs will come. All science rises and falls together in a connected web and we in Congress should not constrain our scientists, our innovators, and our economy by arbitrarily choosing not to invest in certain fields. If we did that we would never have been able to help fund NSF on the gravitational waves.

The National Science Foundation is a direct investment in the future, strength, and vitality of our nation. Companies from my district, like NVIDIA, Google, Apple, and the Silicon Valley Leadership Group are taking it upon themselves to advocate for robust support for the National Science Foundation across all of the fields not just research that directly corresponds to their business. Because they appreciate that it is across all the environment that is innovative, fosters that web and that vitality through the NSF that feeds directly into the ideas and talented employees that their companies need to survive.

Our NSF model has been so successful that countries around the world from Germany to Japan to China have copied the model and are investing heavily in their NSFs. The world's economy is more and more dependent on innovation and as a nation we need to be invested heavily in the National Science Foundation and fundamental research in order to secure a competitive edge in the future economy. This is why I am also disappointed in the President's budget proposal, but in also ignoring the mandatory spending this budget only asks for a 1.3 percent increase. This is subinflation and is not enough. The world is investing heavily in fundamental research across all of the disciplines and so must we.

So I look forward to working with you and Chairman Culberson to find the money to fully support it, that sounds good, does it not? Find the money to support the NSF and continue to grow our innovative environment in the country. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you very much, Mr. Honda. And Director Córdova, your written statement will, without objection, be entered into the record in its entirety. And if we could we would welcome your summary of your testimony and if you could keep it within five minutes we would be very grateful. Thank you very much.

Dr. CÓRDOVA. Thank you very much, Chairman Culberson and Ranking Member Honda, Mr. Kilmer, and all the members of the staff. Good morning. And I must say Chairman Culberson and Ranking Member Honda that your words about NSF and its impor-

tance to the competitiveness of our country are music to our ears. They are just very, very important. So thank you very much for recognizing that and so stating.

I am very pleased to testify today on behalf of the National Science Foundation's fiscal year 2017 budget submission. In my written testimony I have addressed specific aspects of our budget request. NSF believes that this budget comprises a strong request that is responsive to both the national interest in science and science in the national interest. In my oral testimony I will discuss the recent discovery that you both mentioned that highlights the role of the National Science Foundation and the rewards of fundamental research.

As you know, Mr. Chairman, in early February I participated in the historic announcement of the first observation of gravitational waves by NSF's Laser Interferometer Gravitational-Wave Observatory, or LIGO. This observation is a sterling example of how and why NSF exists.

Gravitational waves are ripples in the fabric of space time, arriving at the Earth from cataclysmic events in the distant universe. Although Albert Einstein predicted their existence in 1916 their direct observation was a daunting, seeming impossible task. Einstein himself thought so. Nonetheless technological innovation combined with sound theoretical underpinnings were so tantalizing that NSF began funding research in this area in the 1970s. In the 1980s NSF committed to a full-blown observatory with two widely separated sites for positive confirmation of any detection. LIGO in fact was the first of what we call the MREFC projects, or Major Research Equipment Facilities Construction projects for NSF, and it prompted highly productive discussions with Congress. Even though NSF had never funded to that date anything on such a scale, the potential for transformative science was worth it.

With the National Science Board's approval and Congress' support, NSF built LIGO, one of the most precise scientific instruments ever developed, able to monitor the Earth's expansion and contraction to a tiny fraction of the width of the nucleus of an atom. This is a feat comparable to measuring the distance between our sun and the nearest star to about the width of a human hair. The detection of a gravitational wave was made a mere four days after turning on this advanced instrument. That wave arose in the final fraction of a second during a merger of two massive black holes approximately 1.3 billion years ago.

More than a thousand scientists worked in the LIGO scientific collaboration at universities around the states and in 14 other countries. I am pleased to add that nearly half of those scientists are from institutions and states represented by your subcommittee.

This discovery is truly a beginning, not an end. It confirms a major prediction of Einstein's General Theory of Relativity, marks the birth of gravitational wave astronomy, an entirely new way of looking at the universe. This historic achievement illustrates the importance of the National Science Foundation and really exemplifies its role in advancing discovery. The majesty of exploring our universe motivates such ambitious experiments but as with all fundamental science it also offers other benefits that are important to the nation.

For example, the science will advance education, inspiring students and developing the work force our society requires. I think that just as NASA's Moon shot enticed me and so many others of my generation to become scientists, so too will the LIGO result attract young people into science.

The fruits of NSF supported research drive our economy, enhance our security, and ensure our global leadership. As you know, basic research is uncertain and risky, but it can be revolutionary. LIGO is a striking example, but not the only one. Nobel Prizes that mark transformative discoveries, in fact, have been awarded to 217 researchers funded by the National Science Foundation. Fundamental research has transformed our world and will continue to change it in ways that we have not yet imagined.

Mr. Chairman, the budget request before you builds on the Foundation's strong success as the place where discovery and discoverers begin. Our 6.7 percent, or $500 million, increase will place special emphasis on the early career researchers needed to realize tomorrow's breakthroughs. With the fiscal year 2017 request we will be able to fund nearly a thousand early career faculty.

NSF always seeks ways to quicken the pace of discovery. Key to this is enabling early investigators to sustain momentum from their graduate training by investing in them early in their faculty appointments. This strategy would be a downpayment on sustaining our nation's long term competitiveness.

NSF funds thousands of small steps, some more successful than others. Einstein said, "One should not pursue goals that are easily achieved. One must develop an instinct for what one can just barely achieve through one's greatest efforts." This was also the advice I got as a graduate student, aim high for understanding the really big stuff.

With your continued support NSF looks forward to making further discoveries like the one I just discussed that advance our understanding of the origin and evolution of our universe and everything within it, including ourselves.

This concludes my testimony and I will be pleased to answer any questions.

[The information follows:]

Dr. France Córdova
Director
National Science Foundation

Before the
Committee on Appropriations
Subcommittee on Commerce, Justice, Science and Related Agencies
United States House of Representatives

on
The President's Fiscal Year 2017 Budget Request
for the National Science Foundation

March 16, 2016

Chairman Culberson, Ranking Member Honda, and Members of the Subcommittee, it is my privilege to be here with you today to discuss the National Science Foundation's (NSF) fiscal year (FY) 2017 Budget Request.

The cornerstone of NSF is the merit-based, competitive process that fosters the highest standards of excellence and accountability. The programs and practices which the hard-working and dedicated staff at NSF have created have been emulated around the world, and they have nurtured the creative talents of hundreds of thousands of scientists, engineers, students and educators in every part of the U.S. Their work has also supported the discoveries of some 217 American Nobel Prize winners who represent about 70% of all U.S. Nobelists since 1950.

NSF's comprehensive and flexible support of meritorious projects enables the Foundation to identify and foster both fundamental and transformative discoveries and broader impacts within and among fields of inquiry. NSF has the latitude to support emerging fields, high-risk ideas, interdisciplinary collaborations, and research that pushes – and even creates – the very frontiers of knowledge. In these ways, NSF's discoveries inspire the American public – and the world.

The NSF mission is to look toward the frontier – to identify the most innovative and promising new research and education projects. NSF specifically targets its investments in discovery research at the frontiers of science and engineering. Here, advances push the boundaries of innovation, progress, and productivity.

We identify such frontiers by sticking to our proven, "bottom-up" philosophy. The best ideas come directly from the scientific and engineering community. No better example comes to mind

than the recent first direct detection of gravitational waves by NSF's Laser Interferometer Gravitational-Wave Observatory (LIGO). This historic discovery first began to be funded by NSF in the 1970's as a transformational idea to prove one of the predictions of Einstein's theory of General Relativity. This detection will continue to push the boundaries of science and discovery for decades to come and illustrates the importance of NSF and its role in advancing discovery.

NSF is the only federal agency with a mandate to support research and education in every discipline. The results of frontier research have a long record of improving lives and meeting national needs. They are the very bedrock of economic growth; the path to sustainability in energy, agricultural, and environmental domains; the seeds of the next technology revolution; and the foundation for advances in medicine. Sustained momentum in NSF's programs is essential for progress in science and engineering. NSF's broad scope uniquely positions us to integrate the natural sciences and engineering with social, behavioral, and economic sciences to address the complex societal challenges of today.

The Foundation's annual budget represents just four percent of the total federal budget for research and development, but accounts for 24 percent of the total federal support for basic research conducted at U.S. colleges and universities, and this share increases to 60 percent when medical research supported by the National Institutes of Health is excluded. In many fields NSF is the primary source of federal academic support.

To fuel the innovations of the future, NSF continues to support fundamental research and education in all fields of science and engineering to maintain a global edge in the competition for new ideas and the most talented people. The core science and engineering disciplines form the "building blocks" for future innovations. NSF supports the new ideas and approaches needed to advance interdisciplinary research which is a hallmark of contemporary science and engineering. In all these activities, we keep a steady focus on the frontier, where discoveries, and discoverers, begin.

THE NSF FY 2017 BUDGET REQUEST

The FY 2017 Budget Request for the National Science Foundation (NSF) continues NSF's longstanding commitment to supporting research that drives scientific discovery, maintains America's global competitiveness, and builds the modern workforce that is critical for addressing the complex challenges that face the Nation. NSF is vital because we invest in basic research and people who make the discoveries that transform our future. Those discoveries are a primary driver of the U.S. economy, enhance our Nation's security, and give the country the competitive edge to remain a global leader.

NSF's FY 2017 Budget Request is $7.964 billion, an increase of $500.53 million (6.7 percent) over the FY 2016 Estimate. This includes $7.56 billion in discretionary budget authority and $400 million in new mandatory budget authority. The FY 2017 Budget Request reflects a carefully chosen portfolio that supports the fundamental research that is NSF's hallmark and

creates and sustains key partnerships with other federal agencies, industry, and international entities. Through sustained, longstanding investments in all areas of science, engineering, and education, this submission ensures a robust return on investment for all American citizens. NSF's broad portfolio positions the agency to contribute productively and rapidly to important national challenges. For example, the Computer Science for All initiative, announced by the President on January 30, 2016, builds on ongoing NSF activities that foster rigorous and engaging computer science education in schools across the Nation. Similarly, a range of NSF-supported advances and innovations will help to launch the Administration's cancer "moonshot." These include fundamental research in biology, biochemistry, biophysics; data-driven discovery enabled by machine learning techniques and leveraging NSF-cyberinfrastructure; and engineered systems in nanotechnology, imaging, material science and robotics.

FY 2017 MAJOR EMPHASES

NSF's FY 2017 Budget Request includes two areas of major emphasis: Clean Energy R&D and strengthening support for core activities, with a special focus on support for early career investigators.

The President joined other world leaders at the recent Paris climate negotiations to launch "Mission Innovation", a landmark commitment to dramatically accelerate public and private global clean energy innovation, by investing in new technologies that will define a clean, affordable, and reliable global power mix. Through this initiative, the U.S. and 19 other countries have committed to doubling their governmental clean energy research and development investment over five years. Successful innovation in clean energy requires broad participation, including nontraditional approaches and innovators close to stakeholders that will benefit from clean energy solutions. Mission Innovation provides a robust framework to expand and better integrate clean energy research across agencies. The Budget for NSF includes $512.22 million for investments in Clean Energy R&D. NSF's clean energy portfolio supports research and education in innovative renewable and alternative energy sources for electricity (solar, wind, wave, geothermal) and fuels (chemical and biofuels). NSF funding also addresses the collection, conversion, storage, and distribution of energy from diverse power sources, including smart grids; the science and engineering of energy materials; and energy use and efficiency, including for computing systems. Clean energy research addresses our advancement toward reliable and sustainable energy resources and systems that preserve essential ecosystems and environmental services, promote positive social and economic outcomes, and prepare society to responsibly adopt them.

New one-year mandatory funding totaling $400 million will support the fundamental, curiosity-driven research that is NSF's principal contribution to the Nation's science and technology enterprise. In particular, this funding will support more scientists and engineers at the early stages of their careers – who bring particular expertise in data- and computationally-intensive activities – to quicken the pace of discovery and advance the leading edge of research and education. This funding will allow for an estimated 800 additional research grants to be made from a pool of highly-rated proposals that would otherwise be declined for lack of funding. This additional funding would bring NSF's FY 2017 funding rate to an estimated 23 percent.

FY 2017 CROSS-FOUNDATION INVESTMENTS

NSF continues to bring together researchers from all fields of science and engineering to address today's cross-disciplinary questions and challenges through Foundation-wide activities. In FY 2017, NSF continues to support its four FY 2016 cross-foundation investments.

Understanding the Brain (UtB) ($141.62 million) encompasses ongoing cognitive science and neuroscience research and NSF's contributions to the Administration's Brain Research through Advancing Innovation and Neurotechnologies (BRAIN) Initiative. The goal of UtB is to enable scientific understanding of the full complexity of the brain in action and in context. Priorities include: brain-inspired concepts and designs; development of innovative technologies, tools and instrumentation, computational infrastructure, theory, and models to understand the brain; identification of the fundamental relationships among neural activity, cognition, and behavior; understanding how the brain responds and adapts to changing environments and recovers from lost functionality; and BRAIN workforce development and training for the next generation of neuroscientists and neuroengineers. Improved understanding of the brain will promote brain health; enable engineered solutions that enhance, replace or compensate for lost function; improve the effectiveness of formal and informal educational approaches; and lead to brain-inspired smarter technologies for improved quality of life. Basic research in these areas will also offer novel insights into how cognitive abilities develop and can be maintained and improved throughout the lifespan.

Risk and Resilience ($43.15 million) investments aim to improve predictability and risk assessment and increase preparedness for extreme natural and man-made events in order to reduce their impact on quality of life, society, and the economy. NSF is uniquely positioned to support such improvements that require multidisciplinary expertise in science, engineering, and education, such as understanding the dynamic processes that produce extreme events, how people respond to extreme events, and how to engineer resilient infrastructure, including in the context of smart and connected communities. One supporting program is Critical Resilient Interdependent Infrastructure Systems and Processes, which directly addresses the need for the resilient and reliable infrastructure that is critical to U.S. economic competitiveness and national security. Another is Prediction of and Resilience against Extreme Events, which aims to enhance the understanding and prediction of, as well as resilience and sustainable responses to, extreme events and geohazards, and their impact on natural and human systems.

Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) ($62.18 million) is an NSF-wide investment that aims to understand, design, and model the interconnected food, energy, and water system through an interdisciplinary research effort that incorporates all areas of science and engineering and addresses the natural, social, and human-built factors involved. Throughout NSF, activities address food, energy, or water, such as Water Sustainability and Climate and Hazards; Coupled Natural and Human Systems; and Basic Research to Enable Agricultural Development. INFEWS, however, is the first program to study the interconnected food-energy-water nexus. The need for this program is increasingly urgent, as growing U.S. and global populations, changes in land use, and increasing geographic and seasonal variability in

precipitation patterns are placing an ever-increasing stress on these critical resources. NSF, through INFEWS, is uniquely poised to focus not only on the fundamental science and engineering questions at this nexus, but to train the next generation of researchers in this interdisciplinary area.

NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science), is an integrated, national initiative to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved and/or under-represented in the science, technology, engineering, and mathematics (STEM) enterprise. In FY 2017, NSF investment in this key priority is $16.0 million. Building on activities underway in FY 2015 and FY 2016, NSF will proceed to full implementation of NSF INCLUDES in FY 2017. Investments aim to produce, through alliances organized within a national network, rapid progress on changing the balance of diversity in science and engineering, have significant national impact for the participation of underrepresented groups, stimulate the community, forge new partnerships, and catalyze new approaches. NSF INCLUDES will build on and amplify other NSF investments in broadening participation.

FY 2017 Ongoing NSF-Wide Priorities

NSF invests in a number of ongoing Foundation-wide programs that focus on addressing the most pressing challenges that face our Nation today. Foundation-wide programs and priorities bring together researchers from all fields of science and engineering to work on projects no one field can address on its own. These interdisciplinary investments are carefully balanced with a longstanding commitment to the fundamental research that addresses grand challenges and furthers basic scientific knowledge.

- **Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS)** ($257.12 million) aims to integrate a number of science and engineering activities across the Foundation – breakthrough materials, advanced manufacturing, and smart systems, which includes robotic, cyber-physical, and autonomous systems. It will address pressing technological challenges facing the Nation and promote U.S. economic competitiveness in a variety of sectors. In FY 2017, CEMMSS continues to leverage key interagency activities, including the Administration's Materials Genome Initiative, Advanced Manufacturing Partnership, and the National Robotics Initiative. Through CEMMSS, NSF also invests in Advanced Manufacturing ($175.74 million) to advance cutting-edge manufacturing, as described in the *National Strategic Plan for Advanced Manufacturing.*

- **Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21)** ($100.07 million) accelerates and transforms the process of scientific discovery and innovation by providing advanced cyberinfrastructure that enables new functional capabilities in computational and data-enabled science and engineering across all disciplines. CIF21 has a planned sunset at the end of FY 2017, but efforts will inform a subsequent, focused set of activities for FY 2018 as a part of the Administration's new National Strategic Computing Initiative (NSCI).

- **NSF Innovation Corps (I-Corps™)** ($30.0 million) improves NSF-funded researchers' access to resources that can assist in bridging the gap between discoveries and speed knowledge transfer to downstream technological applications and use at scale. In FY 2017, NSF will continue to support I-Corps™ Nodes and I-Corps™ Sites to further build, utilize, and sustain a national innovation ecosystem that helps researchers effectively identify viable market opportunities and augments the development of technologies, products, and processes that benefit the Nation.

- **Research at the Interface of Biological, Mathematical, and Physical Sciences (BioMaPS)** ($29.81 million) involves the Directorates for Biological Sciences and Mathematical and Physical Sciences, and it seeks to advance discovery at the intersections of these established disciplines. Research includes activities such as development of models, informed by statistical physics that establish the mechanisms linking the biological function of chromosomes to their cellular structure.

- **Science, Engineering, and Education for Sustainability (SEES)** ($52.48 million) supports investments to increase understanding of the integrated system of supply chains, society, the natural world, and alterations humans bring to Earth, in order to create a sustainable world. FY 2017 is the last year in which funding will be formally associated with the SEES portfolio; however, through the planned sunsetting, SEES continues to support important scientific contributions and will make significant progress towards achieving programmatic goals through projects currently underway. Several SEES components with significant community interest will be continued through core programs.

- The **Secure and Trustworthy Cyberspace (SaTC)** ($149.75 million) investment aims to build the knowledge base in cybersecurity that enables discovery, learning and innovation, and leads to a more secure and trustworthy cyberspace. Through a focus on long-term, foundational research, SaTC will develop the scientific foundations for cybersecurity research for years to come. SaTC also focuses on the training of the next generation cybersecurity workforce, especially for government. SaTC aligns NSF's cybersecurity investments with the national cybersecurity strategy.

ADDITIONAL HIGHLIGHTS

NSF continues to emphasize investments in important or emerging areas that have been developed in recent years. For example:

- NSF aims to increase the operational efficiency of **U.S. activities in the Antarctic** ($23.50 million) by continuing progress on a multi-year commitment toward more efficient and cost-effective science support as recommended by the U.S. Antarctic Program Blue Ribbon Panel report, *More and Better Science in Antarctica through Increased Logistical Effectiveness*. Emphases include investing in cargo-carrying capabilities for the South Pole heavy traverse, adding to its ability to deliver fuel, as well as continued investment in vehicle fleet and lifecycle capital equipment purchases to modernize Antarctic inventories and ensure facilities efficiency. This includes targeted investment in information technology infrastructure upgrades such as network management hardware, as well as design work for a new satellite earth station to move the primary communications facility from Black Island to McMurdo

Station. Included in the total investment for FY 2017 is $5.0 million for the Antarctic Infrastructure Modernization for Science (AIMS) preconstruction planning project.

- In FY 2017, support for several of NSF's **astronomy and astrophysics** facilities investments reaches a decision point. A 2012 portfolio review was conducted under the auspices of the Advisory Committee for the Directorate for Mathematical and Physical Sciences in order to align budget realities with the 2010 National Research Council decadal survey, "*New Worlds, New Horizons in Astronomy and Astrophysics.*" Based on these recommendations, NSF is developing potential divestment options for several facilities. In a constrained budget environment, this is the best path to doing new things on the frontiers of astronomy.

- As the CIF21 investment sunsets in FY 2017, NSF will develop a subsequent, focused set of activities aligned with the Administration's new **National Strategic Computing Initiative (NSCI)** ($33.20 million) in order to focus efforts on advancing the Nation's computational infrastructure for science and engineering research. The rich topic of "Big Data", encompassing data science, data assimilation, data management, data policy, community building, and workforce development, will remain a strategic focus under the new NSF Data for Scientific Discovery and Action (D4SDA) activity, which will span research and research infrastructure.

EDUCATION AND STEM WORKFORCE

NSF's education and STEM workforce investment, centered in the Directorate for Education and Human Resources (EHR), funds activities that support students, teachers, researchers, and the public. The EHR investment in core STEM education research is critical to building the Nation's knowledge base for improving STEM learning. In keeping with the Administration's priorities and the strategic goals for STEM education as described in the Federal STEM Education Strategic Plan,[1] NSF's investments for FY 2017 focus on the following priorities:

- The **CyberCorps®: Scholarship for Service (SFS)** program ($70.0 million) supports cybersecurity education and research at higher education institutions. SFS also focuses on workforce development by increasing the number of qualified students entering the fields of information assurance and cybersecurity, which enhances the capacity of the United States higher education enterprise to continue to produce professionals in these fields to secure the Nation's cyberinfrastructure. In FY 2017, $25.0 million of the total funding will lay the groundwork for SFS alumni to be available over the course of their careers to serve the federal government to help respond rapidly to cybersecurity challenges.

- **Computer Science for All (CS for All)** ($20.0 million) will build on ongoing efforts to enable rigorous and engaging computer science education in schools across the Nation. Funds will support the development and assessment of prototype instructional materials, scalable and sustainable professional development models, approaches to preservice preparation for computer science teachers, and teacher resources. CS for All will also fund

[1] National Science and Technology Council. Federal Science, Technology, Engineering, and Mathematics (STEM) Education 5-Year Strategic Plan www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

research that will add to knowledge of effective approaches to the teaching and learning of computer science across grades K-12.

- The **Improving Undergraduate STEM Education (IUSE)** ($109.0 million) initiative supports the development of the STEM and STEM-capable workforce by investing in the improvement of undergraduate STEM education, with focus both on attracting and retaining students, and on degree completion..

- Through the **Advanced Technological Education (ATE)** ($66.00 million) program, NSF is able to reach technicians in undergraduate programs preparing for the high-technology fields that drive our Nation's economy. The ATE program is actively engaged in connecting community college educators funded by the program to the Institutes for Manufacturing Innovation within the National Network for Manufacturing Innovation.

- The **Graduate Research Fellowship (GRF)** ($332.16 million) program recognizes students with high potential in STEM research and innovation and provides support for them to pursue multidisciplinary research. GRF fellows may participate in Graduate Research Opportunities Worldwide (GROW), which provides opportunities to conduct research with international partner countries and organizations, and Graduate Research Internship Program (GRIP), which provides professional development through research internships at federal agencies. An NSF-wide strategic plan for investment in graduate education will be released in FY 2016.

- **The NSF Research Traineeship (NRT)** ($58.63 million) program invests directly in the development of the STEM workforce, and in the improvement of the education of tomorrow's STEM workforce. NRT funds proposals to test, develop, and implement innovative and effective STEM graduate education models, to promote interdisciplinary and broad professional training of graduate students, and to foster fundamental research advances in support of national priorities. NRT thus provides a mechanism for developing a knowledge base about the implementation and impact of innovative graduate traineeship programs and graduate education policies.

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

In FY 2017, NSF requests funding to begin construction of one new project, the Regional Class Research Vessel (RCRV), and to continue construction of two projects, the Daniel K. Inouye Solar Telescope (DKIST) and the Large Synoptic Survey Telescope (LSST).

- The **Regional Class Research Vessel** (RCRV) ($106.0 million) project will initiate construction of two ships to meet anticipated ocean science requirements for the U.S. East Coast, West Coast, and Gulf of Mexico consistent with the recent report, *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*.[2] The RCRV project is a major component in the plan for modernizing the U.S. Academic Research Fleet (ARF).[3]

[2] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences
[3] National Ocean Council. Federal Oceanographic Fleet Status Report, 2013
www.whitehouse.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

- The **Daniel K. Inouye Solar Telescope** ($20.0 million) will enable the study of magneto-hydrodynamic phenomena in the solar photosphere, chromosphere, and corona at unprecedented spatial, temporal, and wavelength resolution to gain information on the creation, interaction, and ultimate annihilation of solar magnetic fields. Determining the role of magnetic fields in the outer regions of the Sun is crucial to understanding the solar dynamo, solar variability, and solar activity, including flares and coronal mass ejections. These can affect civil life on Earth through the phenomena generally described as "space weather" and may have impact on the terrestrial climate. FY 2017 is year nine of an eleven year construction process. In FY 2017, the Coudé rotator platform will be commissioned and accepted. The installation of the Telescope Mount Assembly (TMA) electrical systems will be completed, and commissioning and acceptance testing of the TMA will begin. The Coudé lab room will be complete and various components of the Coudé optics system installed. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered, assembled and will begin initial checkout.

- The **Large Synoptic Survey Telescope** ($67.12 million) will be an 8-meter-class wide-field optical telescope designed to carry out surveys of the entire sky available from its site. LSST will collect nearly 40 terabytes of multi-color imaging data every night and will produce the deepest, widest-field sky image ever. It will image the entire visible sky twice per week, as well as issue alerts for moving and transient objects within 60 seconds of their discovery. The LSST surveys will result in a comprehensive data set that will enable hundreds of other fundamental astrophysical studies by the entire research community. FY 2017 is year four of a nine-year construction process. In FY 2017, work on the summit facility will be completed with the installation of the dome. The telescope structure will be factory tested and shipped to the site for installation. Integration of the innovative primary-tertiary mirror into its support cell will begin, and polishing of the secondary mirror will be finished. The camera cryostat will be made, the first sensor raft will be completed, and the camera's active support structure will be delivered. The data management project expects to deliver its initial archive and finalize the interface to the dedicated education and public outreach system.

ORGANIZATIONAL EXCELLENCE

NSF seeks to integrate mission, vision, and core values to efficiently and effectively execute our activities and provide the flexibility and agility required for all aspects of its operations. This goal incorporates a culture of continuous improvement to ensure effective, inclusive, and accountable programs and merit review processes that provide the greatest value for taxpayer dollars.

In FY 2017, the primary drivers of the increase for the Agency Operations and Award Management (AOAM) account are the headquarters relocation, the 1.6 percent cost-of-living adjustment and related salary and benefit increases, and information technology investments supporting DATA Act requirements, implementation of electronic invoicing, system updates, and increased security. AOAM also supports operational activities to ensure the Foundation has sufficient resources to fully fund ongoing operational requirements and maintain essential

services as we approach the transition to the new NSF headquarters. These include strengthening capabilities in administrative services and human resource management.

CUTS, CONSOLIDATIONS, SAVINGS, AND LOWER PRIORITY PROGRAM

NSF's FY 2017 Request follows a thorough examination of programs and investments across NSF to determine where the potential exists for more innovative investments. This Request includes two proposed terminations, one reduction, and two administrative savings, totaling $46.10 million.

- **Enhancing Access to the Radio Spectrum (EARS)** (-$16.0 million) is a cross-cutting program initiated in FY 2012 whose purpose was to fund interdisciplinary research that enhances the efficiency with which radio spectrum is used and/or leads to greater access to wireless services for all Americans. EARS was a partnership of the Directorates for Computer and Information Science and Engineering (CISE), Engineering (ENG), Mathematical and Physical Science (MPS), and Social, Behavioral, and Economic Sciences (SBE) to support research in new wireless communications and spectrum sharing architectures and services. In FY 2017, CISE, ENG, and MPS will terminate investment in EARS, but will continue ongoing support of research for wireless communication, spectrum sharing, and mobile computing as well as the development of wireless and spectrum testbeds. SBE's support concluded in FY 2014.

- **Integrated NSF Support Promoting Interdisciplinary Research & Education (INSPIRE)** (-$25.35 million) was aimed at strengthening NSF's support of interdisciplinary, potentially transformative research within the directorates by complementing existing efforts with a suite of innovative Foundation-wide activities and funding opportunities. Based on external reviews of the INSPIRE portfolio, coupled with evidence from ongoing cross-cutting programs among directorates, NSF has determined that targeted funding is not necessary to encourage the kinds of projects supported through INSPIRE. Starting in FY 2017, each directorate will continue support for interdisciplinary research through core and cross-cutting programs, coordinating with other directorates and divisions, as necessary, for internal review of these projects.

- **National Solar Observatory (NSO)** (-$3.50 million) is reduced as part of the planned transition away from existing NSO facilities (NSO Integrated Synoptic Program, Dunn Solar Telescope, and McMath-Pierce Solar Telescope) and toward the Daniel K. Inouye Solar Telescope (DKIST).

- **Strategic Human Capital Support Contracts** (-$810,000) funding is decreased due to NSF's planned investment in business intelligence and other tools, supported in the FY 2016 Request, which are anticipated to reduce the cost of contract support.

- **Information Dissemination** (-$440,000) costs associated with maintenance and support of the NSF website are decreased due to a recent retirement of dated infrastructure and the conversion of content to modern platforms.

Concluding Remarks

Mr. Chairman, I've touched on just a handful of programs found in NSF's diverse and vibrant portfolio. NSF's research and education activities underpin the nation's innovation enterprise. America's present and future strength, prosperity and global preeminence depend directly on fundamental research. The scientific and economic record of the past 30 years is proof that an investment in R&D is an investment in a secure future.

NSF's portfolio is continually evolving as we identify and pursue new research at the frontiers of knowledge. An essential part of our mission is to constantly re-think old categories and traditional perspectives. This ability is more important than ever, as conventional boundaries constantly shift and disappear – boundaries between national goals, between disciplines, between science and engineering, and between what is basic and what is applied. NSF, with its mandate to support all fields of science and engineering, is uniquely positioned to meet the needs of researchers exploring human knowledge at these interfaces, whether we're organizing interdisciplinary conferences, enabling cyber-sharing of data and information, or encouraging new collaborations and partnerships across disciplinary and national borders. No other government agency comes close to our flexibility to support STEM education and high-quality basic research.

With intense global competition for knowledge and talent, we must focus our attention on finding the sophisticated solutions that will ensure a prosperous, secure, and healthy future for the nation and the world. We must continue to pursue new understanding about the universe, and our planet within it. Robust NSF investments in discovery research have returned exceptional dividends to the American people, expanding knowledge, improving lives, and ensuring our security. To keep those benefits flowing, we need to constantly replenish the wellspring of new ideas and train new talent while serving as good stewards of the public trust. That is the fundamental and continuing mission of NSF.

Mr. Chairman and members of the Subcommittee, I hope my testimony explains how the Foundation plays a vital role in ensuring that America remains at the epicenter of the ongoing revolution in research, innovation, and learning that is driving 21st century economies. More than ever, the future prosperity and wellbeing of Americans depend on sustained investments in our science and technology. NSF has been and continues to be central to this endeavor.

I hope that this overview has given you a taste of how important the National Science Foundation and its activities are to the future prosperity of the United States. I look forward to working with you in the months ahead as we continue to advance science and engineering in the national interest, and I thank you for your leadership.

I will be pleased to answer any questions you may have.

LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY

Mr. CULBERSON. Thank you very much, Dr. Córdova. The LIGO gravitational-wave experiment that you just talked about, were you able to tell the direction from which the wave came or where the black hole merger occurred?

Dr. CÓRDOVA. Only very approximately because there are just two facilities, the one in Hanford, Washington and the other in Livingston, Louisiana. And so with just two we could describe a very large arc on the sky where the source could come from. So it excluded a large portion of the sky but it was not a small enough positioning to be able to really say with any definiteness where the source came from. So that is why we need other observatories. And you might know that there is a gravitational wave observatory that is coming online in Italy towards the end of this year and there are others in the early stages in Japan and even India has expressed a desire to be involved. So the more that we have widely distributed around the globe the more precise the positioning will be able to be done. It is just triangulation, basically, and we need more.

Mr. CULBERSON. How do they work? And what was the U.S. investment in the LIGO?

Dr. CÓRDOVA. The U.S. investment over all time and it has been a long time, four decades, is about $1.1 billion. And we have had contributions of approximately $400 million from the 14 other countries I mentioned. And that has paid for the facilities themselves, so that is between $400 million and $500 million. And the rest has been to fund all the people involved for that very long time.

Mr. CULBERSON. Sure. How does it work? And what are the implications of the discovery for what we know about the universe and how it works? Why is it important?

Dr. CÓRDOVA. Why is it important? We want to understand at a very fundamental level the forces of nature and what was responsible for the origin and evolution of the universe and everything within it, including life itself. And we understand very well some aspects of the forces that exist, like electromagnetism, the weak force, the strong force. We understand gravity. But we do not have a unified theory of how all these forces work together. And this has been a pursuit that even Einstein thought about a lot, of how to unify gravity with the quantum mechanics that was just being developed around that time, around the 1920s and 1930s. And so there have been a number of theories, including string theory, that have tried to develop a unified theory that understands gravity and the other forces and quantum mechanics all together as one coherent theory to explain our universe. But that still is a mystery out there, like so many other mysteries we have.

So what this gravitational wave detection does is it opens a new way of observing the universe, namely the gravitational wave spectrum, which we hope, because of the precision of technology now in the new facilities I mentioned coming online, and improvements in our own facilities because that is surely coming as well, will become as well-developed as the electromagnetic spectrum for observation. We think of x-rays and gamma rays at the high frequency end of the electromagnetic spectrum, and then optical and ultra-

violet radiation in the middle frequencies, the ones we are more sensitive to with our eyes, and then the long wavelength low frequency electromagnetic radiation like infrared and radio waves. So that is a very well explored spectrum. And as you know, NASA has pioneered it up in space above the atmosphere. But we have not similarly been able to exploit the gravitational wave spectrum because we just have not had to date the technology that is required.

LIGO observes in a certain frequency regime, obviously one that can detect giant colliding black holes and we hope also supernova remnants. But gravitational observatories in space and observatories like the South Pole telescope can observe other parts that are at lower frequencies of the Gravitational-Wave spectrum. And hopefully we can put together a coherent picture of sources that we may not even know exist eventually with more detectors.

Mr. CULBERSON. When were gamma rays and x-rays first detected?

Dr. CÓRDOVA. They were detected really with the space program, the advent of the space program. So actually——

Mr. CULBERSON. But x-rays were first seen over 100 years ago.

Dr. CÓRDOVA. Well x-rays detected, yes, here with radium and other elements that produce x-rays. But not x-rays from the universe. That is what I thought you meant.

Mr. CULBERSON. Correct.

Dr. CÓRDOVA. But x-rays obviously, and Madame Curie, and many others were involved, and Rontgen, and other scientists. So that was way back a couple of hundred years ago.

Mr. CULBERSON. Right.

Dr. CÓRDOVA. Absolutely. But it was not until we got rockets——

Mr. CULBERSON. Sure.

Dr. CÓRDOVA [continuing]. And then satellites above the atmosphere we could detect them from——

Mr. CULBERSON. Yes, I just mentioned it because what an extraordinarily exciting time to be alive when you can begin to discuss here the concept of a gravitational wave spectrum.

Dr. CÓRDOVA. Right.

Mr. CULBERSON. That is an extraordinary concept and very exciting to be alive at this moment in history. And for us to be able to help make sure this continues, that we continue to expand the width of our ability to perceive and detect gravitational waves. Now we are starting with obviously the brightest and the biggest source of gravitational waves and it is just an extraordinary discovery and we congratulate you. And who knows, maybe with the work that we do in expanding America's space program maybe we can eventually have a GRACE type spacecraft using lasers and we can go to the outer solar system and we can expand your gravitational wave detection using lasers similar to the GRACE spacecraft measuring the distance between the spacecraft here at Earth and then far out in the solar system to measure the, did you say the width of an atom?

Dr. CÓRDOVA. Yes.

Mr. CULBERSON. Is the detection capability of the LIGO?

Dr. CÓRDOVA. Yes.

Mr. CULBERSON. And that is what enables you to see——

Dr. CÓRDOVA. Yes, of actually a proton, one ten-thousandth the size of the width of a proton. Very, very sensitive, very tiny deviation in the fabric of space time.

Mr. CULBERSON. The distance between these two observational points deep within the Earth, I understand they are very deep in the ground?

Dr. CÓRDOVA. No, these are not. We would like to invite the committee to come and see the facility.

Mr. CULBERSON. I am thinking about the neutrinos. This is, I am thinking about neutrinos.

Dr. CÓRDOVA. You are thinking about the neutrinos. But these are above the ground facilities. The one in Japan is going to be underground, but ours are not. You can visit them and walk the length of the facilities, which is about four kilometers, each arm is. There are beautiful facilities in Louisiana. I have been to both facilities, and by the way, the one in Louisiana has a tremendous education visitors center. So the public can learn about what gravitational waves are and how the interferometer works and it has many different hands-on experiments for the public.

Mr. CULBERSON. Thank you very much. Mr. Honda.

DIRECTORATE-LEVEL FUNDING

Mr. HONDA. Thank you, Mr. Chairman. And maybe that is what we need, take our subcommittee there on our next trip. And thank you again for being here. My question is last year we heard concerns from NSF, the National Science Board, and the broad science and higher education communities about Congress appropriating specific funding levels for each of the six NSF research directorates. Could you speak a little about this type of directorate level micromanaging and what impact does this have on NSF's ability to set priorities and fund the best science proposals? And then what would be lost if NSF had less flexibility within the research and related activities account? And lastly, how does NSF determine the funding levels for the six science directorates within the R&D activities account?

Dr. CÓRDOVA. Thank you, Mr. Honda. As you know, we very much value the opportunity to have science set the priorities for what we do. We think that is the healthiest way to ensure discoveries at the frontiers have this input from the science community. So let me start with how we set our priorities.

We have, as you know, a very vigorous science and engineering community, which is very diverse. And they come together in workshops and in decadal committees to help set priorities. They come together under the aegis of the National Academies of Science.

Mr. HONDA. Excuse me. Decadal meaning every——

Dr. CÓRDOVA. Every ten years, yes. And they come together through their scientific societies, through the academies, and through our advisory committees, each directorate has such a committee too. So we take all this input and so that is the bottoms-up priority setting. And as you know, in some areas they are very clear about what is of the highest priority for making great advances for the next decade. And we generally follow suit. We try to adapt our budget request to follow the highest priorities in science.

Of course it is a very careful balancing act. We never know, as your own remark said when you opened, Mr. Honda, you never know where the next big discovery is going to come from. We fund all of science and engineering so we try to have a very balanced portfolio approach to what we fund and how we look at these priorities set by all the different communities.

We put them together in a budget that is carefully reviewed by our leadership of these different directorates and by their advisory committees. And it is eventually judged by the community themselves what that budget request is going to look like. And we are hopeful that it is interdisciplinary enough to allow the flexibility for discoveries to be made that are very surprising. Sometimes we know what we are after, like detecting a gravitational wave, and sometimes these discoveries are amazing and we absolutely cannot predict where they come from.

So our major concerns regarding the designation of funding amounts within the Research and Related Activities account, which embraces the six directorates, are that it would undermine the cooperation that we see across our organizational units that is a defining characteristic of our current budget development process. And it would jeopardize the agency's flexibility to pursue promising emerging opportunities, and it would minimize the value of input from the scientific community through these different processes.

We think if we did have specific directorate level funding, it would make the whole process very highly politicized and we would lack a reliable mechanism for incorporating expert advice into science and our legislators would be. Instead of the science community coming together with proposals on what is of the highest priority from all the different disciplines, they would go directly to you and insist that their science was the highest priority. And it would be a very unstable way of funding science because when one committee is here and helping, and then it changes over and we have new people in the legislature, we could have ups and downs in funding that would make it very unstable to have consistent funding for science.

So for all those reasons we think it is really not a good idea and not supported by the science community to have directorate-level specific funding by directorates.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you. Mr. Jolly.

Mr. JOLLY. Thank you, Mr. Chairman. And thank you for being here. I have got a series of kind of unrelated questions. The first one is ATE. Can you maybe touch on the trend line with ATE? The value of supporting community colleges and the contribution they might provide? How that fits into the broader basic research portfolio?

Dr. CÓRDOVA. Yes, Mr. Jolly. And hello, I am glad you are here. The Advanced Technological Education program is a very important way of embracing all the talent that is in our community colleges and ensuring that they are part of enhancing the STEM workforce. That is the short answer. We are just very concerned that we want to be inclusive, that is the main thing that NSF is concerned about. And to welcome all comers into potential science and engineering careers. And to also become science literate. There

are a lot of opportunities in the workforce that are not only being a professor in a university that are extremely important in this highly technological society.

So the ATE program, I believe our request is something like $66 million for this year. It is just a very important part of our portfolio.

Mr. JOLLY. Is that fairly level funded? And I apologize for asking.

Dr. CÓRDOVA. Yes. Yes, it is. I have the person, Joan Ferrini-Mundy——

Mr. JOLLY. Sure.

Dr. CÓRDOVA [continuing]. Who is, yes, that is what I remember. The actuals are in 2013 it was $63 million, and as I said today it is $66 million. So I would consider that fairly level funding.

Mr. JOLLY. Sure. Very good. And thank you for your commitment to that. You know, it is, quite often we hear about the additional need not just for well educated tech supporters to support perhaps the basic researchers, but also the contribution they make in a lot of communities like mine to advanced manufacturing and a manufacturing sector that is coming to rely on more and more educated tech graduates, if you will, that can support that. So ATE clearly contributes to it.

NEW MANDATORY FUNDING

Second question, again I am going to jump around a little bit, the $400 million in new mandatory spending. Can you, and I apologize if the chairman has addressed this, can you address that request? You know, mandatory kind of jumps off the page——

Dr. CÓRDOVA. Right.

Mr. JOLLY [continuing]. When you see it in a budget request.

Dr. CÓRDOVA. Right. Well I would like to take a different approach than the chairman took. And just to let you know, the chairman basically said we were not likely to get mandatory funding. But what the important thing is, if we were to get it, what we would use it for.

Mr. JOLLY. Is it creating stability? I mean, I know on the investigator side one of the issues is always stability of funding. But why mandatory?

Dr. CÓRDOVA. It is stability funding. Our funding success rate, let us call it, the number of proposals that are successful as a fraction of the folks that are proposing them, has gone down in the last couple of decades from something like 40 percent to 20 percent overall. So that is a huge drop. And I know part of it of course is increasing the numbers of proposals, but that is after all what we are trying to do as a country, namely, get people more involved in making discoveries, discoveries that can lead to innovation. And so regarding the $400 million, we found when we did analysis of this statistic that it is actually the early investigators, that is those within a dozen years of their Ph.D., who have the lowest success rates. And that is for a variety of reasons. They are early. They are first-timers. They may not know all the ropes. It is a very vulnerable stage of their career——

Mr. JOLLY. Sure.

Dr. CÓRDOVA [continuing]. Because it is one where they could make the Nobel Prize discovery; they have got young, creative

minds. And by not getting their proposal accepted, they could go in another direction and we could lose them to the science and engineering workforce. And so what we would do is direct that $400 million towards increasing the success rate of early investigators with a special emphasis on data-intensive training. Because we believe that understanding data, big data analysis and data science, is just so important to the future of our country in all fields.

DIRECTORATE-LEVEL FUNDING

Mr. JOLLY. And one last question. And I know you addressed Mr. Honda's question about directorate specific funding. And look, I do not think we need to bring politics into science. And on my side of the aisle I am one that is happy to accept science. But in a, kind of lay terms to ask the question, is the concern over directorate specific funding because there is political interests in the administration that are different than those that might be in the Congress? Or is it because you want the discretion to allocate funding where you think the likelihood of the greatest breakthroughs are?

Do you understand the difference in that? For instance, there are certain priorities of the President that might be different than the Congress, and he has that prerogative to do so. So is that what you are trying to protect? Those political and policy priorities? Or is it protecting the discretion to pursue certain breakthrough areas?

Dr. CÓRDOVA. It is the latter, for sure. You know, if you just look at the levels of the funding for the different disciplines you can see that there is enormous difference between, say, math and physical sciences, which is at the high end, and social and behavioral sciences, which is the low end.

Mr. JOLLY. OK.

Dr. CÓRDOVA. With the science community and all of us coming together and over time, there is priority. But the priority is set by the potential for breakthrough and by the needs of communities. I mean, one can argue that some do not need big facilities, big telescopes, big ships and so forth.

Mr. JOLLY. Sure. OK. Thank you, and I know my time is up. I yield back.

Mr. HONDA. Would the gentleman, Mr. Chairman, if he would yield for a second just to clarify the reason for my question, and it is a good one, because it is the pressure that individual policy makers may face also from——

Dr. CÓRDOVA. Right.

Mr. HONDA [continuing]. The different communities, science communities, come to us first or, you know, lobby us before we move forward any issues on policy or funding. And if the scientific community can get together and do that among themselves rather than the industries, they can do it with the scientists, or if they do it with us I think it is like putting the cart before the horse. And it is an undue pressure I think that we do not need to have until we hear from the science community. That was the reason for my question. Thank you for that question.

Mr. CULBERSON. Mr. Kilmer.

WORKFORCE AND COMPETITIVENESS

Mr. KILMER. Thank you, Chairman, and thanks for being back with us. I have got a couple of questions that are mostly focused on issues around workforce and our competitiveness. And the first gets at kind of broad issues around digital literacy. I think increasingly the capacity of people who are entering the workforce to use technology to solve problems by applying basic digital skills and use of the internet is increasingly important. And yet in 2013 the OECD conducted a study that found that American young adults ranked near the bottom for using digital skills to solve problems. And I am worried about what that means in terms of our ongoing competitiveness. So I wanted to get a sense from you of how you think we can improve disparities around the use of digital literacy, around digital literacy? And can you talk to me about how NSF approaches these issues and whether NSF ever teams up with organizations like the National Academy of Sciences to develop policy recommendations and whether there would be an openness to doing that regarding how to increase access to digital literacy and curriculum and some of those broader issues?

Dr. CÓRDOVA. Thank you, Mr. Kilmer.

Mr. KILMER. Sure.

Dr. CÓRDOVA. Well first of all, NSF definitely would agree that digital literacy is very, very important. We do team up with the National Academy. We do ask them to do many different studies and we think this is a very important area. We would welcome teaming with them.

We also, yesterday I met with the Secretary, Dr. King, of Education and we talked about this very subject in the context of a new program that we are funding together called Computer Science for All. You may have heard of it. We are just rolling it out. And Computer Science for All is about involving K through 12 more in computer science. And this is just getting going but we talked specifically about digital literacy and how important it is for teachers, too, and maybe some extra teacher training during summer months, should they wish, would also help and how that could help with digital literacy in schools. And then the last thing is NSF just announced a new program called INCLUDES. Its goal is to increase the access to everyone and specifically women and underrepresented minorities, lower socioeconomic students, that do not presently have access to STEM fields including computer science. And we just put out a call. I sent a letter to every university chancellor, and college president in the country, asking them for innovative proposals of how to do this. How to reach out in broad partnerships with the community and really move the needle on participation in STEM. So I see opportunities for innovation, including digital literacy, in that program as well.

Mr. KILMER. Thank you for that. And that is certainly an important issue in my neck of the woods. I also along those lines wanted to ask about workforce around addressing cybersecurity. And I know the President recently outlined a cybersecurity national action plan and a piece of that was focused around cybersecurity workforce. The plan describes efforts to improve cybersecurity education programs by developing cybersecurity curriculum and ex-

panding scholarship programs. And I know that NSF already leads the Cyber Corps scholarship program. So I wanted to get a sense of what role the NSF is going to have in implementing the President's plan and specifically given your relationship with some of the higher education stakeholders do you see NSF as being able to assist in both the development and roll out of a cybersecurity curriculum and providing a link between stakeholders in government and academia and industry?

Dr. CÓRDOVA. Yes. We think this is a very important program and opportunity. I believe we have something like $20 million extra in our request for the Cybersecurity Scholarships for Service program. I think what we are going to be emphasizing is how we can provide education and training for a reserve corps of the folks that do get these scholarships so that they can be called upon for service to agencies, others that need cybersecurity specialists. So that is where our money is going to go, to what kind of a program can we develop for a reserve.

And as far as working with universities, I have had a number of university presidents in my office who have described new curriculum. They are already on board. More recently the President of Stanford, John Hennessy, was describing a new curriculum at Stanford, but several others as well, that is focused on cybersecurity for students. So I think the combination of us providing scholarships with just the desire on the part of students. We are experiencing, our advisory committee to computer science tells me, a tidal wave of students interested in computer science in general and cybersecurity of course is a really important part of that.

Mr. KILMER. Thank you. Thank you, Mr. Chairman.

DECADAL SURVEYS

Mr. CULBERSON. Thank you very much, Mr. Kilmer. Dr. Córdova, if I could I wanted to follow up on the, I have always been a big fan of the decadal surveys when it comes to NASA.

Dr. CÓRDOVA. Yes.

Mr. CULBERSON. I have included language in our bill this year to encourage NASA to follow the recommendations of the decadal survey in each of the major survey areas and am delighted to hear that you have got a similar process that I look forward to learning more about. But if you could just reiterate some of what you said to Mr. Jolly and describe for us how is their decadal survey process at the National Science Foundation? And how do they map out a blueprint for the decade ahead for the type of research that you need to do?

Dr. CÓRDOVA. OK. So the——

Mr. CULBERSON. What did you mean when you said there was a decadal survey?

Dr. CÓRDOVA. The decadal surveys are not for each agency. Really they are subject matter surveys and they apply to all the agencies that are engaged in funding that subject matter. So if you take astronomy and astrophysics, so I am really familiar with this one since I am an astrophysicist, and I participated in past decadal surveys for that field.

So they would put on the table the priorities of the community, independent of whether they could or should be funded by NASA or NSF or NOAA, USGS.

Mr. CULBERSON. Sure, that makes sense.

Dr. CÓRDOVA. Then we look at those priorities, we say what best matches what our specific mission and our facilities are? So in astronomy and astrophysics the kind of rough way of saying it is we mainly do stuff on the ground, whereas NASA is mainly focused on space. There are collaborations, of course, with both. And so in the most recent astronomy survey the LSST was named as the number one priority in the decadal survey.

Mr. CULBERSON. Synoptic——

Dr. CÓRDOVA. That is the Large Survey Synoptic Telescope. NSF is funding that one. It is a ground based telescope. It is being constructed in Chile. And so that is an example. And there would be other recommendations for NASA and so forth.

Mr. CULBERSON. Do you then meet with NASA officials and decide who is going to take what piece? Or do you collaborate with NASA, for example?

Dr. CÓRDOVA. No, NASA has other inputs as well that will be focused on NASA missions and will be priorities specifically for space. There are places where we are funding things together. But they would be like NASA utilization: to support its space missions they would be using some telescopes on the ground.

I wanted to mention another example, which is the ocean sciences decadal survey. That is a survey that we just got the results from about a year ago January. And there were recommendations for balancing infrastructure with PI science, individual investigators and so on. And their recommendation was that, because we had previously had on the table maybe building three new research vessels, was to do two vessels so we could lower the infrastructure and operating costs and focus the rest of the budget on individual investigator science.

Mr. CULBERSON. Also produced by the National Academy?

Dr. CÓRDOVA. Yes, it was sponsored by the National Academy. But when you say produced, we and other agencies fund the National Academies to do studies. OK? So that is the way it works.

Mr. CULBERSON. So then do you collaborate with NOAA, for example, to decide what portion of the oceanographic decadal that they will fund and follow versus the portions you——

Dr. CÓRDOVA. Well I do not know how NOAA does it. They will have these decadal——

Mr. CULBERSON. You do not talk to them?

Dr. CÓRDOVA. We do. In fact we have a committee that we co-chair, an infrastructure committee. It is called the Interagency Working Group for Facilities and Infrastructure that NSF and NOAA co-chair, I believe. And this sets out the priorities for using all scientific inputs for the academic research fleets, actually for the whole Federal research fleet. And they produce a report every three years and I believe one is almost ready for Congress. It is about to be released. And so that will talk about specific things for NOAA, specific items for NSF, and ONR, and so forth. But yes, there is a lot of collaboration. It is just that we need to appreciate that we have different missions.

Mr. CULBERSON. Correct. Of course.

Dr. CÓRDOVA. Yes.

Mr. CULBERSON. But there is no formal standardized procedure to collaborate with either NOAA or NASA to decide what portion of the decadal you are going to work on versus NASA or NOAA?

Dr. CÓRDOVA. Yes.

Mr. CULBERSON. It sounds like it is sort of an informal process.

Dr. CÓRDOVA. It is very collaborative and these working groups they have written a very elaborate report. So I think I would call it formal——

Mr. CULBERSON. OK.

Dr. CÓRDOVA [continuing]. In that sense.

Mr. CULBERSON. The reason I ask is I want also to avoid directorate level funding.

Dr. CÓRDOVA. Right.

Mr. CULBERSON. I think it is important that we not insert——

Dr. CÓRDOVA. Yes.

Mr. CULBERSON [continuing]. Political agendas from either end of the political spectrum, from any part of the political spectrum, in the work that the scientific community does. But I am very impressed with the work of the decadal survey that the National Academies have done in their decadal surveys. And that is why I included language in our 2016 bill to ensure that the National Aeronautics and Space Administration, we gave them direction to follow the decadal recommendations because of the superb quality of the work. It is a blueprint for the next decade.

Dr. CÓRDOVA. Yes.

Mr. CULBERSON. It allows us as members of Congress——

Dr. CÓRDOVA. Right.

Mr. CULBERSON [continuing]. To recognize what the priorities are of the scientific community in their best objective judgment and fund those priorities and make sure that they are carried out. Because these discoveries, as the gravitational wave discovery, has taken a couple of decades to achieve.

Dr. CÓRDOVA. Right.

Mr. CULBERSON. These are long term, very expensive, very difficult achievements that we cannot always be sure——

Dr. CÓRDOVA. Yes.

Mr. CULBERSON [continuing]. When we make the investment at the front end where it is going to wind up at the back end.

Dr. CÓRDOVA. Yes.

Mr. CULBERSON. And we do need to keep political judgment out of the work that you do as much as possible. I mean, there is a lot of concern on our side, for example, we do not want for example the climate change work that is being done to be driven by political agenda from either direction. We just want the facts, as Joe Friday said, on Dragnet. We just want the facts so we can make——

Dr. CÓRDOVA. Right.

Mr. CULBERSON [continuing]. It is our job as policy makers to make good decisions based on accurate, objective, factual data. That is all we are looking for. So the decadal survey is of keen interest to me and I am glad Mr. Jolly asked the question. Because that was something I intended to pursue with you separately and privately and I am glad he brought it up. Because we need to have,

I think, a decadal survey, or find a way to have a decadal survey for the National Science Foundation, as NASA has for the space program, so we can see as policy makers what the next decade——

Dr. CÓRDOVA. Yes.

Mr. CULBERSON [continuing]. What the needs are for the next decade—

Dr. CÓRDOVA. Yes.

Mr. CULBERSON [continuing]. What amount of money will be necessary. Frankly I would love to also, I have been working with Mr. Fattah and Mr. Honda, all the members of this subcommittee, I really want to cut the Office of Management and Budget out of the loop for NASA and the National Science Foundation. I do not think the bean counters, the bureaucratic bean counters at OMB should be substituting their judgment for the work that you do or the work that NASA does. They ought to be able to give us an accurate, honest assessment——

Dr. CÓRDOVA. Yes.

Mr. CULBERSON [continuing]. Of what your needs are——

Dr. CÓRDOVA. Yes.

Mr. CULBERSON [continuing]. And what the, you should be able to tell us directly what your financial needs are so we can fund those based on a blueprint from the National Academy of Sciences in a decadal survey format so we can make an honest, objective assessment of what the needs are and then fund those and then get out of the way. And just the facts, ma'am, as Joe Friday said. I am there. I am with you, 110 percent, and want us to get there.

So anyway, I did not mean to take so much time. I am going to pass it to Mr. Fattah. But do be thinking about how do we create a decadal survey type program? And if it is already there, obviously for astrophysics, heliophysics——

Dr. CÓRDOVA. Yes.

Mr. CULBERSON [continuing]. The planetary sciences, you know, terrestrial and outer planets, how do we divide that up, then? How do we make sure that there is a formal process in place where you are handling portions of those decadals that already exist? What kind of decadal do we need to create for the National Science Foundation in general for the hard sciences, math, you know, the— oh excuse me, I have got to go back to Mr. Honda. Forgive me. But nevertheless, be thinking about it. Because I really think it is important that we have objective peer reviewed scientific recommendations for this committee and the Congress that give us just the facts so we can then make the policy decisions about what money is necessary to be sure America preserves its leadership role in space and scientific research. Mr. Honda.

Mr. HONDA. Thank you, Sergeant Friday.

Mr. CULBERSON. Sergeant? I like that. Sergeant Friday, everyone.

Mr. HONDA. I still remember Jack Webb.

Mr. CULBERSON. Yes.

SOCIAL SCIENCE AND GEOSCIENCE FUNDING

Mr. HONDA. Dr. Córdova, I think there is a lack of understanding about what sort of research is funded by social science directorate. Much of this research has an impact on issues as broad as national

security, responses to major disasters, and strategies to save taxpayers money. And, briefly, can you give us some examples of ways that social and behavioral science funding is researching problems?

And let me hook up with the second part of my question. Geoscience funding is important to the training of many researchers in the academic field, I also understand that many industries in areas as broad as energy exploration, construction, and risk mitigation depend on NSF funded training for their employees.

Can you tell us about the importance of geoscience funding to the private sector? It is sort of a follow up on all this discussion about the directorate, but I wanted to break out the social and behavioral science and the earth science.

Dr. CÓRDOVA. Sure. Well, I think you all know that the Social, Behavioral, and Economic Sciences Directorate is the smallest, lowest funded of our research directorates; representing under five percent of the total of NSF's research and related activities account.

But its significance, its importance, to all the other fields belies that fact because we think that almost every area of science is increasingly dependent on social sciences coming into the picture to help make decisions, evaluations, assessments, and optimization of very important decisions.

For example, in how technology is used. As technology becomes more complex, it is increasingly important to have a social science component. Not just how it is used, but why and what kind of decisions have to be made. Also in public health, including personalized medicine, there are social science questions about how people are going to adapt to this, and what kind of decisions people have to make.

There are questions in energy independence, questions in cyber security—another committee had a hearing on this recently and it was discussed that half of the problem in cyber security is a social science problem—how systems are made more secure, and we protect our privacy and all, depends on people. And so understanding this, and how human beings behave in context, is important to understanding how to make ourselves more secure.

You asked for some examples. In social science I think there is a famous example of auction of the wireless spectrum, which is now a $60 billion industry, and the FCC has really benefitted from algorithms that were developed by our social scientists that are applied to the auctioning now.

Another area where social science has really helped us is matching algorithms to support kidney and other organ exchanges. Our social scientists have strategies for assigning students to public schools in urban settings. Those are three examples that are very important social science contributions.

And I think that, for me, it is very interesting that in all of our new initiatives that we have put forward, whether it is in risks and preparations for earthquakes and disasters, or our food, water, energy, nexus programs, or understanding the brain, that social science plays an enormous role together with the other sciences in making progress in science in these fields.

And the final example for social and behavioral sciences is in measurement and data linkage and integration. The Department of

Defense has said, in its operation relevance document, that the fusion of both hard and soft forms of data is critical. The ability to fuse intelligence data with social media, mass media, and behavioral survey data is critical to forming a more comprehensive situational awareness.

For the geosciences, it could not be more important to understand everything about our planet, including the oceans, which is so important to our economy. It is important to our understanding our climate, it is important to understanding life itself because we suspect that the origins of life may be in our oceans, and we study extremophiles, very unusual organisms that live on the bottom of the ocean floor that can tell us a lot about how life evolved.

We study, of course, geology, and rocks, and minerals, and earthquakes. I mean, the planet comprises so much from the bottoms of the ocean to the top of the atmosphere that just has so many mysteries that we do not understand. And we have a big emphasis, of course, on planetary science, NASA does as well, but in order to understand other moons and planets we have to understand our own planet a lot better. So for human viability as well as our understanding of our solar system and planets and beyond, we really need to understand the geosciences.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. CULBERSON. Thank you very much. [Audio malfunction in hearing room.]

FOOD, ENERGY, AND WATER RESEARCH

Ms. ROBY. Thank you. Thank you, Dr. Córdova, for being here today. My home state of Alabama, in the district that I represent in particular, agriculture is the number one industry. And so there is a pressing need to understand the connectedness of food, and energy, and water, and of particular interest is the production, resilience, safety and security of food, energy, and water resources. And so I continue to make the point that agriculture is a major part of our national security.

Farmers, and those in the agriculture industry, must provide not only the food for the nation, but the entire world. And from the recent droughts and heavy rains throughout the U.S. to global market fluctuations and the corresponding impacts on water, our food production and the energy sector is an example of these challenges.

And so in your budget request, you outline $62.18 million for the innovations at the nexus of food, energy, and water systems. And so I would love for you to explain to me how this program, the first of its kind, will study the interconnectedness of food, energy, and water, and how do you plan to help educate and disseminate the results of your work?

Dr. CÓRDOVA. Thank you. Yes, it is a problem in many areas of the country including Alabama, like the American Southwest with its droughts and all, and in many places of the world.

So we started with our SEES program, which dealt with those resources, food, water, and energy, separately and we learned from those that you really have to—and that program is winding down this year—we learned from that program—which has been funded the last several years—that we really have to think of food, water, and energy as a total system.

You know, of course, water can produce energy and it also can consume energy, and food uses energy and water. We now have, with our revolution and capability in computer sciences—specifically data analysis and computer simulation—the ability to put together a more holistic picture of how all these quantities are dependent on each other and what kind of trade-offs can be made.

So there will be basic research that is done under food, energy, water, and understanding these connections better. And there will also be a lot more attention to computer simulation and modeling, and more attention to how one optimizes the decisions one has to make. So let me give you a very specific example to put some concreteness to it.

I was at a university where we funded a decision center, and it is in a middle of an area that has a lot of water shortage problems, has a nuclear power plant to boot, close by which needs water for cooling, it is in a big agricultural area, and it has to worry about both the aquifer as well as ground water that comes from another state.

So it wants to produce food, it wants to use water for all these different purposes. Every county in the state has slightly different needs depending on whether it has a strong aquifer that can last for some time, or it is getting water from another state and having to pay for it. How do you put all that together to make a model to optimize the decisions that mayors and elected officials, county officials, have to make?

And so they have all come together. It is a partnership of the whole state with the university leading it in order to do computer modeling on when and what situations of drought or more water, rainfall and all, one would be using one resource versus another resource. That is just one example.

Ms. ROBY. Sure. And then the second part of the question is, how do you disseminate this information once you begin to see the fruits of the research, and educate the very people that you just alluded to?

Dr. CÓRDOVA. Right. Well, there are several ways to do that. One is the scientists themselves are good at having workshops, and I attended one in D.C. not more than a month ago on food, energy, and water. And they have all these great scientific proposals that they are asking NSF and others to fund, and I think they will make a lot of progress.

And so then the next step in getting that information out is to make sure that we do a good job of disseminating results. And, frankly, you have hit on a very important point, Ms. Roby, a lot of what we learn, we learn as scientists and we share it with other scientists. But especially in this area, and also risk and resilience where we are trying to have people be safer when they have disasters and be more prepared and utilize those results, is really going to depend on more communication.

So I am hopeful that we will, through all the social media that is available to us, put a real emphasis on communicating our results in very clear ways so that the public can use it. In this field, you learn more all the time, the more research you do. But the results we do have, and what we are learning from it, need to be put out to the public more. So thank you for underscoring that.

Ms. ROBY. Absolutely. And, Mr. Chairman, that is certainly our responsibility to continue to follow up with you as you do reach some conclusions, and ensure that Alabama's farmers, and those that utilize these resources, have the ability to benefit from the research that you have done. So——

Dr. CÓRDOVA. Now the nation does have strong agriculture schools, a lot of our universities do, and they are the best, historically, from the old land grant concept, at getting out words to farmers and all. This would be a very good avenue also through their engagement with communities. And I know Alabama does as well.

Ms. ROBY. Thank you. I yield back.

Mr. CULBERSON. Thank you, Ms. Roby.

Mr. Fattah.

Mr. FATTAH. Thank you, Mr. Chairman. Welcome, again.

Dr. CÓRDOVA. Hello.

NEUROSCIENCE FUNDING

Mr. FATTAH. I was at a hearing a few minutes before I arrived here with my colleague from Alabama, where we had Dr. Francis Collins in front of the Labor and Health Education Committee, but it is a pleasure to again thank you for your tremendous leadership as a public spirited scientist in leading the most important basic science organization in the world.

I am interested in a couple of things. One is, I am interested, first and foremost, of course, around my number one priority, the work you are doing in terms of neuroscience. And in particular not just what you propose in this year's budget, but how the work that you are doing in partnership with the national labs around the creation of what we have called a National Brain Observatory, how that work is going on.

And then finally, I am interested in the efforts at the agency to continue to engage women in the sciences through making adjustments that have been done in terms of the grant process so that we don't lose women to other activities in their lives, like developing families and so on, but that we keep them, even as they go through these various phases, engaged in—the National Science Foundation, I think, has taken a fairly revolutionary approach to this, and I want you maybe to share a little with the committee on that.

Dr. CÓRDOVA. All right. Yes. Thank you, Mr. Fattah. So you might know that NSF has doubled its investments in research on the brain from $71 million to $147 million between the years 2012 to 2016. And we think that on a percentage basis, that is very, very responsive when compared with others. Our current roadmap for understanding the brain extends to fiscal year 2017, and we are going to spend much of this year assessing the investments we have made to determine which ones yield the most impactful science.

And this gets back to Ms. Roby's question too, indirectly, at some point you have to evaluate and assess what you have done, gather people around that understanding, and decide what directions to go next. When I get to your women example and inclusion of women, I will use that as another example, but let me continue on the brain for a bit.

In fiscal year 2016, Congress added $3 million to our request budget to fund this effort that you described. And NSF has supported and attended several workshops to determine how the neuroscience community would envision and benefit from a collective approach. Through these activities, the six research directorates—that is all of our directorates—released a Dear Colleague Letter just recently in the last few days called a Phased Approach for Developing a National Research Infrastructure for Neuroscience. We will see what that call brings out. And this articulates a vision for an effort that is supported across all our disciplines.

So we have been successful in formulating a strategy, and there is strong convergence for this vision. We are excited to finish our analysis and let you know where we see the real strength and new directions. As we go towards new programs on the brain, we want to learn from what we have invested in the past few years.

And on women. We have had a program for some time that is called ADVANCE, which is specific funding to universities to increase the progress of women through academic science careers. It has been very, very successful. That is, women starting out as assistant professors and how do you give them the encouragement, the mentorship, the funding in order for them to be successful as scientists, engineers, and then end up as full professors and leaders. And we have many metrics we can share with you that—how successful that has been.

I think, in my mind, the most successful part of that has been insisting on institutional commitment, because once you get the whole institution engaged from the very top—and I, as president of Purdue University, was the PI on our ADVANCE grant—that sends a big message to the whole university that this is something that the leadership cares about.

So we translate that aspect of it to a new program that you alluded to called INCLUDES. And we just put out the Dear Colleague Letter on INCLUDES. Again, I sent a letter to all the presidents and chancellors of universities asking them to be the PIs to make this an institutional commitment, and its goal is increasing the number of women and underrepresented minorities, the disabled, all people who are not part of the current statistics about who is in the science and engineering workforce, through really innovative programs.

And the other thing that we have learned from past programs we have done on broadening participation, is how important partnerships are with the broader community. This cannot be something that is done in one department of one college of one university; it has to be something that is done in a regional sense using what they call collective impact: the whole community really cares about this and comes together, all the way from K through 12, the community colleges definitely.

And some university presidents, Mr. Fattah, have a real vision about how to embrace community college students in this. Because some of our very brightest, but let's say financially handicapped students, end up in community colleges because that is where the resources are, and they are close to home, and so we want to engage them in this. So you can see that I have some passion around

this and I am really hoping for some innovation in this space to do things more differently than we have done in the past.

Mr. FATTAH. Well, I know that the whole committee wants to work with you in this regard. Our country, in terms of production of people with terminal degrees, would be at a standstill except for the inclusion of women who are now earning terminal degrees in a variety of disciplines, that heretofore had not been the case. If we are going to compete with big and populated nations like India and China, we cannot leave people on the bench that need to be in the game. So thank you very much.

Dr. CÓRDOVA. Thank you.

Mr. CULBERSON. Mr. Jolly.

DISASTER RESILIENCE RESEARCH

Mr. JOLLY. Thank you, Mr. Chairman. Couple of quick questions on the disaster resilience research you are doing, a little bit of that portfolio. And I am particularly interested that, if you can discuss it generally, but on the infrastructure side if there are areas of pursuit that NSF is pursuing or following?

Dr. CÓRDOVA. I would have to get back to you on that. I do not know what, in detail, what kind of infrastructure. I know that our engineering directorate is very involved in this together with our geosciences directorate. And so part of this is about identifying risk and part of it is how we can become more resilient.

I know our computer sciences directorate is also very involved and they are doing modeling on what we know and how to improve our knowledge ahead of time for disasters. And our social and behavioral sciences is telling us how people can adapt their behaviors to impending disasters, or ones that have already happened, in order to save lives. I know we fund drone-like things to go into disaster areas.

[The information follows:]

Disaster Resilience Infrastructure

Americans rely upon critical infrastructure systems to provide services such as clean water, electricity, transportation and healthcare. These systems are becoming increasingly interconnected, while our demands on them and the hazards they face grow.

To address our nation's need for more resilient and sustainable infrastructure and enhanced services, the National Science Foundation (NSF) invests in new fundamental research to transform infrastructure, ranging from structural materials, such as high-performance concrete and solar-responsive asphalt, to smart and responsive systems. Frequently, research projects on building and infrastructure systems are multidisciplinary efforts that consider human needs and responses associated with mitigation, preparedness, response and recovery.

Many of NSF's infrastructure investments originate in a cluster of complementary research programs in the NSF Directorate for Engineering, where a number of projects focus on special concerns of coastal structures and communities and use a realistic approach to study multiple hazards, such as wind and water, which frequently occur together. Recent NSF Engineering awards include research on mitigating hurricane risk and increasing coastal resiliency, simulating and predicting hurricane surge and wave impact on coastal structures, monitoring bridge scour during critical flood events, modeling of coastal soil-structure instability, and understanding windstorm loading and fatigue damage for coastal bridges.

In addition, NSF-funded researchers are creating new, high-performance designs for structures subjected to natural hazards, including hazards windstorms (tornadoes and hurricanes), storm surge and tsunamis. Buildings are studied as systems, including soil-foundation-structure-envelope-nonstructural elements, as well as the façade and roofing. Design and systems research provides underlying theory that broadly enables improved performance in many settings.

In one project to reduce regional natural disaster risk, funded by NSF's **Infrastructure Management and Extreme Events** program, a team of researchers from Cornell University, the University of Delaware and East Carolina University is modeling multiple stakeholder decision-making. This project incorporates homeowner models, such as factors that influence flood insurance purchase decision-making, with models of government decision-making, insurer decision-making, competition among insurers, and regional natural disaster losses. The goal is to provide a framework to inform government natural disaster risk management policies and make it easier to identify win-win system wide solutions. (NSF award #1435298)

Interdependencies among critical infrastructure systems can amplify the consequences of an initial failure. A recent award on vulnerability assessment and resilient design of interdependent infrastructure undertaken by researchers at the University of Florida and Florida International University is producing improved understanding of fundamental properties that contribute to the robustness of interdependent systems, such as transportation networks and power systems. This award and other research funded through the cross-NSF activity on **Critical Resilient Interdependent Infrastructure Systems and Processes** (CRISP) will lead to innovations in critical infrastructure, so that communications, power and water supplies, and other

community support functions are strengthened, as these systems perform sustainably and securely, delivering even a broader range of goods and services.

Recognizing the national need for resilience against multiple natural hazards, in 2015 the National Science Foundation (NSF) initiated a new chapter in hazards research with a $40-million investment in **Natural Hazards Engineering Research Infrastructure (NHERI)**. To help better understand and resist the impacts of earthquake, wind and water hazards, NHERI provides a network of shared, state-of-the-art research facilities and tools located at universities around the country. NSF's signature investment in NHERI allows researchers to explore and test ground-breaking designs to protect homes, businesses and infrastructure lifelines, and will enable innovations to help prevent natural hazards from becoming societal disasters. The NHERI program is also a critical investment in America's human capital, providing educational opportunities to students who will engineer our communities and plan our disaster response in the future. Among NHERI's seven current experimental facilities are two that provide a testing ground to advance wind engineering: the Twelve-Fan Wall of Wind at Florida International University, and the Boundary Layer Wind Tunnel, Wind Load and Dynamic Flow Simulators and Pressure Loading Actuators at the University of Florida. (NSF NHERI press release)

NSF strategically invests to translate new discoveries into innovations that offer lasting societal benefits. For example, NSF Engineering Research Centers (ERCs) perform fundamental research and work with public and private partners to create innovative technology platforms and transform industries. One new ERC is developing transformational new ground engineering methods to improve the sustainability and resiliency of civil infrastructure systems, including bridges, buildings, underground construction and resource exploration. The **NSF Engineering Research Center for Bio-mediated and Bio-inspired Geotechnics (CBBG)**, launched in August 2015, investigates natural underground biological processes to engineer the ground in ways that reduce construction costs and environmental impacts, while mitigating natural hazards and existing environmental degradation. The CBBG ERC is led by Arizona State University in partnership with the Georgia Institute of Technology, New Mexico State University, and the University of California, Davis. (NSF award #1449501)

Through NSF's **Partnerships for Innovation: Accelerating Innovation Research** program, a project based at Lehigh University is focused on translating an innovative building envelope system to meet the societal need for improved resistance to natural and man-made hazards, including impacts from wind or water-borne hazards. The insulated wall system, called the comb-tie envelope system, also provides energy efficiency and ease of construction. The system's enhanced features provide several advantages: performance under extreme loads, cost savings, and thermal efficiency when compared to the leading competing composite panel systems in this market space. After prototyping and experimentally evaluating the design's performance, the project will result in a proof-of-concept of the comb-tie envelope system to spur commercialization. (NSF award #1543038)

Mr. JOLLY. Sure, sure.

Dr. CÓRDOVA. But as far as other forms of infrastructure, I just don't know what that would be.

Mr. JOLLY. OK. If you could, and no rush.

Dr. CÓRDOVA. Sure.

Mr. JOLLY. It is from within the portfolio, specifically in the infrastructure area. And I know infrastructure a lot is connected communities and IT and so forth. But my district, in particular, it is one county, it is a peninsula, we are ground zero for everything from flood insurance to other issues related to being essentially at sea level.

And so much of what is debated regarding climate change, and what is the appropriate response to that, ultimately that response ends up resting on some very small municipalities and local jurisdictions that have to address infrastructure issues from underground and utilities to whether you use cement or asphalt on the roads, to whatever those issues might be. So I would be curious if, within the portfolio, there are advances, or at least areas of pursuit, within what I would call hardened infrastructure or actual infrastructure.

Dr. CÓRDOVA. Right. What I would surmise—and this goes back to the Chairman's comments about cooperation with other agencies, because this is certainly an area where a number of agencies are engaged—is that we do the basic research on understanding the phenomenon, and doing the modeling and the simulation, and we would translate that understanding to agencies that are more engaged in actually building things.

Mr. JOLLY. Sure.

Dr. CÓRDOVA. And so that's what I would——

Mr. JOLLY. No, and I understand the role of basic insurance and I understand modeling of extreme events, but as it translates then into basic—or into applied and actual, ultimately, products, that hardened infrastructure in a community like ours. Those are areas of strong interest.

And, again, I use the asphalt/cement example because it was a recent conversation I had about the cost benefit of roads and infrastructures using cement as opposed to asphalt and the ability to withstand certain environmental events, if you will, what it means for infrastructure. And decisions that local cities, counties, municipalities are able to make in the long run. Ultimately, what you are doing on the basic side advances their ability to make decisions years from now.

Dr. CÓRDOVA. And the evaluation of what kind of cement or asphalt to use, right?

Mr. JOLLY. Sure.

Dr. CÓRDOVA. And we do fund centers on optimization of materials, on optimization of power and different power supplies, and so forth. But we do not actually make the things——

Mr. JOLLY. Of course.

Dr. CÓRDOVA [continuing]. And then others.

Mr. JOLLY. Fully appreciate that. But to know that there is basic science research in that field is, frankly, very encouraging for a community that is coastal. And real quickly, I know my time is al-

most up. If you could elaborate at all on the two research vessels——

RESEARCH VESSELS

Dr. CÓRDOVA. Sure.

Mr. JOLLY [continuing]. And the type of ocean research that might support.

Dr. CÓRDOVA. Yes. Well, so I alluded earlier to an interagency working group on facilities and infrastructure for the ocean sciences. And we presently have something on the order of 30, or 30 and a few, vessels that are in the academic fleet, and that is not NSF alone, we just have a small portion of that, but everybody, agencies, academic institutions, and so on. That number is going to go down over the next decade or two—two decades, to about 18 vessels, so about half. So we start out about 35 and it is down to about 18.

The vessels that we have are very old and they are just falling apart, and some of them are sold off for other uses, and some of them are scrapped. And so this interagency group is always looking ahead, in the planning sense that the Chairman alluded to, with how do you plan for the next decade. What kind of vessels do we really need?

So we have come up with these smaller research vessels, which are very efficient, can do observations more quickly, scientific observations, and are less costly than other bigger ships that are not so nimble, and these will be able to do many, many deployments out into the ocean, and many different types of science.

We had a decadal review from the ocean sciences that said that we should build two of these in order to replace a number of research vessels. So that is in our 2017 budget is to get started with those two research vessels. They are more near-the-coastline-type vessels, and they will be deployed as needed around our coastline, because there's only two of them.

Mr. JOLLY. Sure.

Dr. CÓRDOVA. Yes.

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

Mr. CULBERSON. Thank you.

Mr. Honda.

COMPUTER SCIENCE AND BIG DATA

Mr. HONDA. Let me just say this has been really interesting. I appreciate that. Dr. Córdova, advanced computing has played an essential role in powering science and innovation across disciplines and industries, and I commend the administration for pushing advanced computing forward through the national strategic computing initiative to ensure we have the next generation tools, and ecosystem needed to continue world leadership on this.

It is my understanding that the NSF plays a key role in this initiative, researching new technologies, training future developers and users, and supporting computing infrastructure to enable groundbreaking discoveries across science and engineering. What are your plans to ensure NSF continues to fulfill these critical roles as the U.S. moves forward in the next generation of advanced computing?

Dr. CÓRDOVA. Mr. Honda, we have a very vibrant computer and computing and information science and engineering directorate, and they have been supporting high performance computing and its evolution, incorporating newer technology and newer ways of handling software for a very long time.

We believe that—let me put it this way. When I look over NSF and what are the really new things, new contributions, that we can make to the nation, I think you hit on an area that is at the core of everything that we do, and it is going to make just a tremendous difference.

We already have, of course, with NSF Net, which followed ARPANET, made a transformation in taking something that was very localized for a specific group of people and making it available nationwide. NSF was a seminal part of the whole computer infrastructure revolution, and we have kept up with that kind of profile by funding really powerful supercomputers across the nation: Texas, like the one at UT Austin, Stampede, and the Blue Waters at the University of Illinois, and Comet in San Diego, all around the nation, Wyoming, and so forth, each of which has a different capability, a different way of functioning, and, therefore, different access by the scientific community, depending on what their scientific question, what their goal is.

And so these are very, very utilized—in fact, hard to keep up with the demand on these—that the real feature of these is that they incorporate the newest technology, the newest software platforms. They are always evolving because we have very, very smart people in the computer community that come together constantly and have new ways of making operations much more efficient. Presently under review are a couple of supercomputers and how to refurbish them and go to the next level. And so I think we are very much leading this field and being led by scientists in this.

And one of the other really encouraging things to see is that our facilities can be made better by advanced computing, and we have brought together—again with the science community's leadership—groups of people from very different fields to talk about how we can have platforms that are more common and that are shared in order to make our facilities, like NEON, LSST, the solar observatory, all the big facilities that we have, to make them function faster and more optimally and have access for the community.

As you know, big data is just getting more and more important, and it presents opportunities for discoveries in itself, and so we are right on that frontier. We just funded a half dozen big data centers across the country, and so that's another approach besides building the computers themselves is to have approaches to analyzing and extracting maximum information from all the big data that is being generated, by us and everybody else.

I think you can sense the excitement that we have for this. It is a very exciting frontier, and I have really challenged the computer directorate to come up with some big, bold ideas for the next decade that will be transformative in the architecture of the software that will be embraced to do big data faster and to be on top of the very latest developments in this. You know we can't use last century's architecture anymore, we have to really look everywhere for the latest developments.

Mr. HONDA. Thank you. Thank you, Mr. Chairman.

FUNDING RESEARCH IN THE NATIONAL INTEREST

Mr. CULBERSON. Thank you, Mr. Honda.

Dr. Córdova, I am aware that National Science Foundation, under your leadership, has implemented new policies to clarify that the abstract for an award must serve the public—as the public justification for NSF funding by articulating how the project serves the national interest and that NSF has also issued a resolution in May 2015 that strongly endorses the principle that all foundation funded research and education must further the national interest by contributing to the foundation's mission.

Could you explain to us what processes NSF has implemented to ensure that all grants funded are in the national interest?

Dr. CÓRDOVA. Yes, Mr. Chairman, we have done several things in the past year and a half or so. But let me start with the establishing language for the National Science Foundation, which is our mission. And that is a mission by definition, as we were established by Congress, to serve the national interest; so the language says "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense and for other purposes." So all NSF funded research and education must further the national interest by contributing to that mission, NSF's mission.

I have taken several steps to ensure that the national interest permeates NSF and our peer review process to make it more explicit. More than a year ago, I implemented a written policy for NSF staff. So this would be in what is a manual that our program officers use to ensure that every award includes, "a non-technical description of the project, which explains the project's significance and importance." This description also serves as a public justification for NSF funding by articulating how the project serves the national interest, as stated by NSF's mission "to promote the progress of science," and so on.

And in January, our public guidance was updated to conform with the established policy by requiring that, "an NSF award abstract with its title is an NSF document that describes the project, and justifies the expenditure of Federal funds, by articulating how the project serves the national interest." So those words "serve the national interest," are both in the policy for internal guidance to our program officers and in the external guidance to the community. In fact, I released what we call important notices to the community every so often, and one called Number 137, was to all the presidents of universities reminding them of just the language that I said.

In addition, we have made a number of changes. We are right on top of how the titles should be written and we have done statistics on how many titles have changed to make it clear that they serve the national interest; and the abstracts too. And let me give you just one statistic. This past year, our review showed that the titles of 24 percent of our proposals were changed in order to make them clearer, and many more, a fraction-wise, of the abstracts because we now have a new rule that an abstract has to have a nontechnical paragraph as well as a technical paragraph.

And the non-technical paragraph addresses the justification that follows our solicitation requirements. I want to say, on the solicitation requirements—because it is very, very interesting with respect to the bill—that every solicitation says that the proposal will be judged on intellectual merit, so that is serving the progress of science—that is the scientific argument—and that it will be justified on the basis of broader impact. And we actually define in the solicitation what broader impact means.

We have ten things listed under broader impact; eight of those things are listed in the bill itself. So we are already including, in our language for the solicitation, all of those things in the bill, plus a couple more on education and the STEM workforce that are not included in the bill, as a justification. And so I think all those things, the guidance, the policy, the changes, the cooperation of all the staff, and the solicitation announcement itself, has all the elements that are in the bill.

Mr. CULBERSON. Thank you.

Mr. Honda.

SUBAWARDS

Mr. HONDA. The NSF makes awards for large [indiscernible] projects, and awards are numerous sub-awards to the communities responsible for various parts of the project, and, the costs of those sub-awards are often the most significant cost of the project.

What is NSF doing to monitor such sub-awards to ensure that Federal requirements are being followed that costs incurred are reasonable, allowable, and allocable? And sub-awards typically constitute a substantial portion of award costs, sometimes as much as 80 percent, I understand. So when it conducts cost audits, will NSF commit to examining the costs of both the awardee and any of the sub-awardees?

Dr. CÓRDOVA. I can get back to you with more detail on the specific sub-awards. I know for the overall awards that we are about to do incurred costs audits and all.

Mr. HONDA. I would appreciate that.

Dr. CÓRDOVA. But I would like to get back to you on the specific sub-award question.

[The information follows:]

SUBAWARDEE COSTS

NSF has not conducted its own incurred cost audits to date. The NSF's Office of Inspector General (OIG) auditors along with audit support from the Defense Contract Audit Agency have reviewed subawardee expenditures during their audits of NSF prime awardees. A number of OIG audit reports issued between FY2010 and FY2016 have included a review of subawardee costs that has resulted in questioned subawardee costs.

As the NSF starts to procure its own incurred cost audits in the future, NSF will develop a methodology to determine when subaward incurred costs should be reviewed.

INTERDISCIPLINARY RESEARCH

Mr. HONDA. Thank you. Science has become very—as you have been explaining all this morning—have become very multi-disciplinarian in nature, and I believe the NSF recognizes that many of the proposal receives combine elements of multiple scientific disciplines. And when Mr. Fattah was here, he talked about neural

research also, and it sort of reminded me that that is part of the social sciences in terms of how people think and they determine policies.

And I am just of diverging a little bit from my core, my question, but it seems to me that when we look at these kinds of things, and we look at our—the way we do studies, that it is important that we have women involved because if it is purely men, we tend to think in certain ways with certain structures and certain biases, if you will, much of it is learned.

And so having this diversity of thinkers and folks who are present makes a big difference, I think, in the total outcome. But in terms of the multiple scientific disciplines, can you give the subcommittee a few examples, particular where proposals combine elements of physical, chemical, biological, and computer sciences with social behavioral sciences?

Dr. CÓRDOVA. Uh-huh. And you said very, very well, Mr. Honda, the importance of diversity. Big business has stepped up and said how important it is to our economic health to have a diverse work force. And, as you know, industry is very concerned about having more women in leadership positions, specifically.

And certainly in science, it is just tremendously important that we include the different approaches of people in order to do very innovative and new things, and not just be doing what we have been doing in the past.

So your question is about examples. We have—I mentioned already our food, energy, water initiative, which includes many directorates in it, and that has a big social science component in it for—and as Ms. Roby was saying, how do you assess what you have learned? How do you get the information out? What do people do with the information? And is that enough? Is that enough to change things and to really optimize our use of these very precious resources and how they are interdependent?

I mentioned our initiative on risk and resilience, and how important it is to have social scientists assess—well, it is great to know a tornado is coming, and even something about its probable pathway and intensity, but if people do not know what they should do, and when they should do it, and how to respond afterwards, then lives can be lost. And many assessments have shown that, in the case of disasters, new knowledge is not necessarily saving lives, but it is new understanding of what to do with that knowledge that can save lives.

We have programs I have not mentioned. Programs like our BioMaPS program, which is an interdisciplinary opportunity between our biological directorate and our math and physical sciences—that is the MaPS part of it—to do projects in synthetic biology to understand materials better, especially to develop biologically inspired new materials, would be one example.

And there—I think social science also has a role to play, and I have seen it at universities, actually be a part of such collaborations to assess how can technology be used to benefit us rather than be used in ways that are potentially harmful. And students now at some universities are being required to take ethics courses so that they can help make those kind of decisions.

As I said earlier, I think social sciences is permeating the ways that we think about just about everything that is a grand challenge that has to do with people. And so I expect that it is going to become even more important to our portfolio in the future than it is now.

Mr. HONDA. Thank you, Mr. Chairman.

NATIONAL ECOLOGICAL OBSERVATORY NETWORK

Mr. CULBERSON. Thank you, Mr. Honda.

I will do one more set of questions and I believe we need to wrap up. Mr. Honda has a commitment. And I do want to focus, if I could, Dr. Córdova, on the National Ecological Observatory Network. Last year, NSF identified an $80 million cost overrun for the NEON project. And as a result, as required by the NSF, NEON will de-scope the project, which includes decreasing the number of sites from 106 to 82, and I know you have also brought on new management.

If the network is not entirely built, why do you need $65 million additional funding for operations, especially if the network is going to include nearly 25 percent fewer sites than originally planned? And what steps has NSF taken to ensure the program is, quite frankly, properly run, and that you have got a greater degree of rigor in management, and to prevent cost overruns?

Dr. CÓRDOVA. Uh-huh. Well, as you know, the whole process of having opportunity for entities to propose for new management was because we didn't think things were headed in the right direction because of scheduling and cost overruns. And there were, of course, potential schedule and especially potential cost overruns. The schedule is related to cost, and it looked like the schedule was getting out of hand.

And so we had a very intensive process, and we selected a new management entity, Battelle. We have signed an initial agreement, an initial award, to them that was just put into place last Friday so they can assume management responsibility for the project. There will be a 90-day transition period where the final costs to construct and operate NEON will be negotiated between Battelle and the National Science Foundation.

And that has always been the plan—to get them on board as soon as possible because, in their proposal, they have new ideas about how to accelerate the scheduling and, thereby, it may not cost as much. So it is just essential to get them going as soon as possible, but we also have to give them the opportunity to really understand the full cost.

As far as the science is concerned, when we realized last spring/summer that we were facing a potential $80 million cost overrun, we asked the advisory committee to the biology directorate to stand up a task force, if you will, a subcommittee, under their aegis, of top scientists. I mean, these are National Academy standing scientists from around the country to come together and to look at what was proposed originally for NEON and what the budget constraints and all were now, and that we did not want to have a cost overrun, and considering that there was a de-scoping plan on the table, could they assess the de-scoped plan and let us know wheth-

er there was a lot of transformative science to be had with the descoped plan.

And so they did that. They did that on an amazingly short time scale, which just shows the power of the science community to come together and to quickly do such an important assessment. And they came back, and they said that absolutely that they thought that great science could be achieved with the proposed descoping from the number of sites that you mentioned, but no more de-scoping because we do have to preserve the original mission of NEON.

And so we think that by accelerating schedule and also—just to go back to the discussion about computers, and Mr. Honda's questions about how we were involving the best computational capabilities—we think by revolutionizing the computer approaches to this observatory as well, that we can also realize some efficiency in gains.

And so, you know, time will out: we will find out how well we have done, but we think that Battelle has produced an exceptional proposal in every aspect, including involving the science community. And we have very high hopes, and with our very close involvement—and believe me, I have weekly meetings with my senior staff on NEON—that this is an all-hands effort to make sure that this problem is resolved in short order of any potential overruns, and that this program delivers incredible value to the public.

Mr. CULBERSON. So in addition to weekly meetings, what other steps have you formally instituted to be sure that you have got the proper oversight to ensure that Battelle is not—you do not have the same problem you did before with the other management?

Dr. CÓRDOVA. Yes. Yes, very good. So a number of changes have been made in the project management at NSF. We have a new program officer, and that person then reports to a project leader who has all the certifications, is very, very competent in project management. We have transferred the location of the oversight of the project from the main office of biology to the biological infrastructure division where it can be treated as any other project and real project management can be assumed.

I have to say, our large facility office has been splendid under the leadership of Matt Hawkins, and they have hired more people who are certified to help not only with NEON, but with all of our large facilities. We have not talked in this hearing about the NAPA report. As you know, the National Academy of Public Administration gave us a report of recommendations for improving our oversight and management of large facilities, and we have also had biweekly meetings on implementing that plan.

So we are going to, in some sense, adopt every recommendation. Maybe not to the letter, some will be complex and challenging, but we intend to—we have adopted their recommendations as a whole. And those really apply to NEON as well. So we have a lot of changes.

And the last thing I will say is that what I was most concerned with is oversight up to the level of the Director. I want to know what is going on. We are a de-centralized, for the most part, institution. So you can think of a university where the colleges have a lot of decentralization: we are a lot like that.

Through this effort, we are trying to more centralize the things that really affect the entire agency, like large facilities. And so you will see at the end of the day, not today, not tomorrow, but certainly in the next several months, because we have groups working outside, external groups, doing studies of what kind of oversight and internal management structure is optimum, to make sure that everyone knows what everyone else is doing, what's going on more broadly.

Mr. CULBERSON. Thank you very much, Dr. Córdova.

Do have one more question?

Mr. HONDA. Just one last.

Mr. CULBERSON. Sure.

SEXUAL HARASSMENT OF RESEARCHERS

Mr. HONDA. You mentioned NAPA and—thank you, Mr. Chairman for the last opportunity. But very quickly, I have been reading some articles for the past few months and there have been a number of examples of women in science coming forward to bring to life cases of sexual harassment by professors on women researchers. And the three basic questions as to what is NSF doing to combat such harassment in the research community? Should the NSF give grants to researchers who have been found guilty of sexual harassment? And can NSF do more to change this kind of a culture? And I know it is a very sensitive question, but I think it is a——

Dr. CÓRDOVA. A very important one.

Mr. HONDA. It is a situation that needs to be discussed, I think, publicly when we talk about everything else. We talk about diversity and women's input, and things like that.

Dr. CÓRDOVA. Right.

Mr. HONDA. I think that that reading, as sensitive as it is, I would like to know what your response.

Dr. CÓRDOVA. Thank you for the discussion of this issue. NSF and NASA have put out recent statements about sexual harassment and how we view this, so that is on our website, and we take a very strong position as does NASA. And we do say what our expectations are, and then we say that in principle, if universities—you know, we don't make individual grants, we make the grant to the university and then they fund the person—but that if universities do not take this seriously, we have the option to withdraw their funding. So that is one step we have done.

And another step is that in every case that where NSF is the funder, that we are working, as we really always have, through our office of diversity and inclusion, and with the Department of Education, because they have a lot of jurisdiction in this matter. And, by the way, I mentioned that I talked with Secretary King yesterday, and this was an issue I also brought up to him. And I think you are going to see more interaction on this issue with Department of Education as well.

So we take these cases very seriously. As you know, there are privacy laws that are involved, so we have to, you know, be careful about what we say goes out there. But each case is taken on its own merits, or demerits, and we are making adjudications—as far as our role allows us—with the Department of Education on what

we can do to show how serious we are to universities and other entities we fund.

And the last thing, I think this is very important, is that the National Science and Technology Council has a committee on science, which I cochair with Francis Collins at NIH and Jo Handelsman at OSTP. And we, at our March 31st meeting of this month, we will take this up as one of the main issues and I will lead the discussion, so that everyone knows how seriously we take this.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. CULBERSON. I hope your policy is zero tolerance.

Dr. CÓRDOVA. Yes, of course. But I meant the role as far as what kind of punishments would be meted out, that sort of thing, but, of course, it is. And it has affected women tremendously.

Mr. CULBERSON. It is terrific that you are focusing on this and ensuring that everyone is treated with professionalism, respect, and courtesy. Thank you very much for your service to the country. We will have a series of questions we will submit for the record. I ask you to respond to in writing, and with greater specificity. But above all, we thank you for your service. And the hearing is adjourned. Thank you.

Dr. CÓRDOVA. Thank you.

UNITED STATES HOUSE OF REPRESENTATIVES
Committee on Appropriations
Subcommittee on Commerce, Justice, Science, and Related Agencies
Hearing on
National Science Foundation FY2017 Budget Request
March 16, 2016
Dr. France Córdova, Director, National Science Foundation
Questions for the Record Submitted by
the Honorable John Culberson

Regional Class Research Vessels

Question: The NSF fiscal year 2017 budget includes $106 million to begin construction of two regional class research vessels. Please explain why NSF needs new vessels. Can NSF charter private sector vessels to conduct this research? And, has NSF evaluated the costs of chartering private vessels versus buying its own vessels?

Answer: *Please explain why NSF needs new vessels.* The two Regional Class Research Vessels (RCRVs) will provide support for oceanographic research along the U.S. Atlantic East Coast, the Pacific West Coast, and the Gulf of Mexico, as part of the Academic Research Fleet (ARF). As is the case with all ships in the ARF, RCRVs will support research projects funded by the NSF, Office of Naval Research, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, Bureau of Ocean Energy Management, U.S. Geological Survey, and U.S. Army Corps of Engineers, as well as state and private philanthropic institutions.

NSF requires the capabilities of the RCRVs to meet the science needs expected in these coastal waters of the U.S. The ARF is in the process of decreasing its overall number of vessels so as to "right-size" the fleet, and is modernizing the overall fleet capability as part of this process. These are not one-for-one replacements of old, retiring existing vessels. The RCRV ships will provide significantly improved capabilities to meet future science needs. These ships will also be performing some science missions currently supported by larger, more expensive platforms that will be retired. For example, RCRVs will have advanced dynamic positioning to provide the ability to maintain precise sampling locations. They will have enhanced underway geophysical capabilities. They will have high bandwidth communications to involve remote participants, state-of-the-art sonar systems for seafloor mapping, and seawater flow-through systems with numerous sensors that transmit information to databases in real time. These and other features have been selected based on science community involvement with the RCRV design and scrutinized by the RCRV Science Oversight Committee and NSF Design Review panels.

Can NSF charter private sector vessels to conduct this research? The RCRVs will be U.S-flagged, NSF-owned, U.S. Coast Guard-inspected, and University-National Oceanographic Laboratory System (UNOLS) compliant to ensure that the highest possible standards of safety and science capability are provided to the U.S academic research and educational community. Charter vessels do not meet these standards. Charter vessels also do not provide the breadth of reliable technical and engineering capabilities as do ships that are part of the standing ARF. Unlike charter vessels, ARF ships provide well-known, high-quality science support personnel and innovative technologies for federal, state, and other users. Such capabilities are required in order to address the grand challenges posed by cutting edge ocean research. Charter vessels do not provide such know-how. Furthermore, many non-ARF ships are foreign-flagged, are not inspected by the U.S. Coast Guard for safety, and do not meet the even higher standards of UNOLS safety compliance. In the few circumstances where chartering makes sound financial,

scientific, and risk management sense, NSF does so (e.g., for certain types of research in polar regions).

Has NSF evaluated the costs of chartering private vessels versus buying its own vessels? Yes. Chartering private vessels is not cost effective, either for the short term or for the long term. A recent study conducted by NSF to assess the "lease versus buy" approach concluded that it is more cost-effective to lease ships with identical capabilities when the intended use is for up to 10 years. Given that the anticipated operational lifetime of each RCRV is 30+ years, over their lifetime it is significantly more cost-effective to construct new ships compared to leasing commercial vessels. Moreover, federally funded research must be coordinated and scheduled to provide optimal support for science mission requirements. Expeditions are prioritized and retain the authority to conduct science in places and at times when commercial services may not be available. It is also critical for many science missions to have continuity of support systems. For example, many repeat measurements require use of the same vessel for several years to ensure that observed trends are real and not the result of changes in measurement platforms. This continuity is best supported by continued use of the ARF, whereas no expectation of long-term availability can be relied upon to be supplied from outside private vessel sources.

The Interagency Working Group on Facilities and Infrastructure (IWG-FI) has very recently completed a thorough discussion of these and other related issues relating to the Federal Fleet.[1]

Major Research Equipment and Facilities Construction (MREFC)

Question: The Inspector General has issued a series of alert memos on the Large Synoptic Survey Telescope and the Daniel K. Inouye Solar Telescope. NSF has recently descoped National Ecological Observatory Network. What steps has NSF implemented to ensure that these programs are being implemented according to all applicable Federal laws and OMB guidelines?

Answer: NSF has always ensured that these programs are implemented in compliance with applicable federal laws and OMB guidance for cooperative agreements. All of the issues raised by the OIG relate to internal NSF policies and procedures, not federal laws. As a result, NSF has taken substantive effort over the past few years to strengthen its policies and procedures related to cost estimating, contingency management, management fee, and incurred cost audits. This is an on-going effort that NSF takes seriously and it will continue to evaluate and further codify its practices to strengthen government oversight as it deems necessary and appropriate.

For the NEON project specifically, NSF's oversight mechanisms have replaced NEON, Inc. with Battelle as the managing organization to complete construction and initial operations. One key component of this oversight mechanism was NSF's very clear no cost overrun policy, which NEON, Inc. was unable to manage against. NSF also used its new cost analysis procedures to execute an Independent Cost Estimate (ICE) to inform the final award with Battelle. For LSST and DKIST, new requirements for contingency estimating and management have been incorporated, and most recently, Earned Value Management (EVM) validation is now being conducted. NSF's annual portfolio-wide risk assessment also identified LSST (~15 percent complete) as a candidate for an incurred cost audit which will commence in FY 2016. All three projects are in full compliance with NSF's newly published policy on management fee.

[1] www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/federal_fleet_status_report_final.pdf

Questions for the Record Submitted by
the Honorable Steven M. Palazzo

Regional Class Research Vessels

NSF has requested funding to begin construction of two ships under the Regional Class Research Vessel (RCRV) project to meet anticipated ocean science requirements for the United States' East Coast, West Coast, and Gulf of Mexico. This project, as you know, is a major component in the plan for modernizing the U.S. Academic Research Fleet. According to a April 2015 University National Oceanographic Laboratory System (UNOLS) response to the 2015-2025 Decadal Survey of Ocean Science Sea Change report, UNOLS endorsed and recommended the current Regional Class Research Vessel (RCRV) design as appropriate and that it will meet the future needs of seagoing scientists working in U.S. coastal regions. UNOLS further recommended that NSF should continue to build three RCRVs with the third being a "Gulf" vessel.

Question: What is NSF's position on a third RCRV, and what are your observations that this should be a vessel to support Gulf of Mexico research?

Answer: *What is NSF's position on a third RCRV?* A decade-long process for including Research Class Research Vessels (RCRVs) in the Academic Research Fleet (ARF) informed NSF's decision to pursue construction of two ships.

The University-National Oceanographic Laboratory System (UNOLS) responded to a request from NSF to provide its viewpoint given realistic expectations for ship use demand for science and the likely costs to support ARF operations and maintenance. UNOLS' conclusion was that NSF should construct three RCRVs, even if NSF's Division of Ocean Sciences (OCE) budget were to prove insufficient to support the ARF with the resultant number of ships (17). The UNOLS-proposed remedy would then be to retire early other, older less capable ships sooner than their planned exit from the ARF. This recommendation to construct three vessels was consistent with a series of prior planning documents over the past years, such as Federal Oceanographic Facilities Committee reports[2], Federal Oceanographic Fleet Status reports[3], and a few National Research Council reports on related topics.[4,5]

However, the most recent and all-encompassing report from the National, "*Sea Change: Decadal Survey of Ocean Sciences, 2015-2025*",[6] recommended that NSF construct "no more than 2 RCRVs." The Decadal Survey committee was more realistically charged with producing a comprehensive assessment of the balance of OCE spending to support science and infrastructure. The ARF is part of "infrastructure." *Sea Change* recommended reductions of variable amounts throughout OCE's infrastructure portfolio. One *Sea Change* recommendation is that O&M spending for the ARF be reduced immediately by five percent, with still further reductions after five years. Given this reduced level of support, and the long-term budgetary outlook, *Sea Change* recommended that NSF build only two RCRVs.

[2] www.unols.org/sites/default/files/National-Academic-Research-Fleet.pdf
[3] www.whitehouse.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf
[4] www.nap.edu/catalog/12775/science-at-sea-meeting-future-oceanographic-goals-with-a-robust
[5] www.nap.edu/catalog/13081/critical-infrastructure-for-ocean-research-and-societal-needs-in-2030
[6] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences

Given these recommendations, and after significant internal discussion, NSF concludes that constructing two RCRVs, resulting in a 16-ship ARF, will concentrate ship use demand such that robust, and thus efficient and cost-effective, schedules will result. Conservative estimates for the planned reduction in overall O&M support for the ARF will allow for two RCRVs to operate fully. This assessment is responsive to the desires, as well as the concerns, expressed by external stakeholders including ship operators, ship users, and the broader ocean sciences community.

What are your observations that this should be a vessel to support Gulf of Mexico research? The two RCRVs will meet research demand in all three coastal regions of the U.S. (East, West, and Gulf of Mexico). Which institution is awarded a cooperative agreement to operate a RCRV, where a vessel would be home-ported, and where it will perform scientific research, are three distinct aspects of the discussion. For the RCRV project, Oregon State University was awarded a cooperative agreement for design and construction, as well as the opportunity to operate the first vessel, as proposed in its response to NSF solicitation 12-558.[7] Also described in the NSF solicitation is the intention to compete operation of subsequent RCRV(s) to serve the needs of U.S coastal science in the most efficient and effective way possible. NSF intends to issue a solicitation for the operation of the second RCRV if and when the funds to continue construction, and thus support exercising a shipyard contract for a second vessel, are requested. This process is expected to begin in February 2017. Part of the operator selection decision will be based on where the greatest need for science support exists, and how operator institutions that respond to the opportunity can meet that need. It is therefore not yet decided if a second RCRV would be operated out of the Gulf of Mexico or on the U.S East Coast. Regardless of that decision, however, the second RCRV will operate in support of research throughout the coastal U.S., not just the coast where it is home-ported or where its operating institution is located.

[7] www.nsf.gov/pubs/2012/nsf12558/nsf12558.htm

Questions for the Record Submitted by the Honorable Jaime Herrera Beutler

Basic Research

Question 1. In 2012 NSF awarded over $2 billion in tire research over five years. This is a significant amount to be spending on any specific research project, let alone a project on tires. I understand you may not know the outcome of every award granted, but seeing as this award is close to completion and is about 6% of your overall total budget over the last 5 years, what return on investment have we seen from this research? Have we seen an increase in driving safety as this award promised?

Answer: The grant in question is to the Center for Tire Research (CenTire), an Industry / University Cooperative Research Center (I/UCRC) led by Virginia Tech University and in partnership with the University of Akron. CenTire provides a forum for industry/university collaboration focused on emerging technologies of tire materials, manufacturing, modeling, and testing. CenTire currently has 17 corporate members that pay annual membership fees to support the research conducted by the universities. The industrial members include Bridgestone, Ford, Eastman Chemical, Goodyear, Cooper Tire and Rubber Company, PPG Industries, and others. The companies help define the pre-competitive research agenda, select the research projects to be conducted, and provide mentorship to each project. The universities conduct the research in collaboration with the companies. The industrial members of CenTire have access to the intellectual property resulting from the center's research on a non-exclusive, royalty-free basis.

The total research funding provided by NSF to CenTire is $2,013,991. Please note that this is approximately $2 million and not $2 billion, per the reference in the question. Included in this total funding is $1,153,616 awarded in fiscal year 2015 under a grand challenges program focused on integrating multiple I/UCRCs and other partners to solve specific problems of national importance. The recent grand challenges award to CenTire focuses on a research problem in alignment with the Advanced Manufacturing Partnership 2.0 (AMP2.0), Advanced Materials Manufacturing (AMM)'s call for efforts aimed at the design and synthesis of new materials, as well as innovative approaches to processing of traditional materials. The research emphasizes the processing of advanced structural composites using embedded sensing, measurement, and control systems with scalable IT platforms, so it has applicability beyond the tire industry to aerospace, intelligent automobiles and other vehicles, and other fields where composites are critical. In a concerted effort with industry participants, the program will develop and demonstrate the manufacturing approach required for embedding self-powered piezoelectric and dielectric based sensors into soft matrices such as rubber in tires and flexible plastics in seat belts while ensuring compatibility with the commercial environment.

The partnership includes the I/UCRC for Tire Research, the I/UCRC for Broadband Wireless Access and Applications (BWAC), the I/UCRC for Energy Harvesting Materials and Systems (CEHMS), and the NSF Nanosystems Engineering Research Center (NERC) for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST), and their industry members.

Question 2. Further, the inherent nature of research is that it may or may not result in the desired outcomes. How do you ensure that the personal agenda of the awardee does not influence the accuracy of the results?

Answer: In order to answer the question, it is important to put forth a number of ideas. First, academic science is conducted by communities of researchers that define a field through their discoveries, which, in turn, form the basis for peer-reviewed publications in the science journals within their fields. Second, current scientific communities build new knowledge out of the discoveries and innovations of those that came before them. Third, each community has its own professional societies that develop the ethical standards by which all agree to adhere in order to remain upstanding members. Fourth, in science, one "wins" by having ones discoveries remain meaningful over significant periods of time. They become the fodder for future discoveries.

Given these four ideas, one can presume then that any given scientist greatly values his or her reputation within that community over the course of his or her lifetime. Members of that community attend the same conferences, read the same journals, and submit and review papers to and for the most prestigious journals in their area, attempting to both get their own best ideas into print as well of those of their colleagues. If one's result is not well justified or if the methodology used is flawed, it probably will not get published. However, some ideas may be published that are not borne out over time. When faced with a new and complex phenomenon, multiple theories may arise to explain it. Publishing these competing ideas, and experimental results or observations, is an important part of science. This allows other researchers to gather new observations or devise new experiments. Eventually the preponderance of accumulated evidence increases researchers' confidence in one explanation over another and the impact of the explanations that are demonstrated to be incorrect fades. If someone intentionally falsifies data to get a result, it will be discovered soon either because others who attempt to reproduce those results in their own work find that they are unable to do so or because new results are obtained that show the old ones to be inconsistent. When someone is found to have intentionally falsified their results, they suffer negative consequences. They may be fired from the university. They may be disbarred from ever submitting proposals to federal funding agencies. Their ideas are no longer taken seriously by their peers. In other words, the consequences for their professional career are serious. One is essentially ostracized from the research community.

The science and engineering research and education communities have evolved over the centuries to be self-policing and have developed a set of principles, incentives, and constraints that support the integrity of their research output. Their reputations depend on this.

Elementary STEM Education

Question 3. Equipping our children to compete in the global 21st century economy, and focusing on STEM education is a priority for me. How has NSF furthered this priority for elementary school children, ages 5-10?

Answer: NSF invests in equipping our children to compete in the global 21st century economy by offering and funding specific program activities focusing on STEM education. The Directorate for Education and Human Resources' (EHR) programs that prioritize STEM education for elementary-age children are described below:

The Discovery Research PreK-12 (DRK-12) program (NSF 15-592[8]) seeks to significantly enhance the learning and teaching of STEM by PreK-12 students and teachers through research and development of STEM education innovations and approaches. Projects in this program are intended to result in research-informed and field-tested outcomes and products that inform teaching and learning. Of the over 500 awards made by DRK-12 since 2007, 40 percent have addressed the needs of elementary school students and teachers.

The Advancing Informal STEM Learning program (NSF 15-593[9]) focuses on STEM learning opportunities available in such out-of-classroom settings as museums and libraries for all age groups, including children 5-10 years old and families. This program also funds educational television programs, including award-winning programs for preschool and primary-aged children.

The Robert Noyce Teacher Scholarship program (NSF 15-530[10]) supports the recruitment and preparation of STEM majors and professionals to become K-12 teachers. A considerable number of Noyce Scholars are preparing to teach elementary school and will bring strong disciplinary knowledge to young learners.

The EHR Core Research program (NSF 15-509[11]) continues to expand and deepen its portfolio of foundational research on STEM learning for any age group. Early childhood STEM learning is an area of emphasis in both FY 2016 and FY 2017.

Reflecting NSF's keen interest in this area, in December of 2015 EHR hosted a public Open House that showcased its leading funded researchers on early childhood STEM education. Some topics included early learning about science and engineering in informal environments, early predictors of mathematics and science achievement, the role of executive function in early learning, and connections between social-emotional development and early mathematics and science learning.

Reducing Wasteful and Duplicate Spending

Question 4. Seeing as our national debt is over $19 trillion, cuts must be made to wasteful and duplicate spending. What one area can be cut in the National Science Foundation?

Answer: The National Science Foundation's FY 2017 Budget Request to Congress proposes two program terminations, one program reduction, and two areas of administrative savings, totaling $46.10 million.[12] The Enhancing Access to the Radio Spectrum and Integrated NSF Support Promoting Interdisciplinary Research and Education cross-cutting programs are proposed for termination. Funding for the National Solar Observatory facility is permanently reduced in FY 2017. NSF will achieve efficiency improvements that provide administrative savings for the agency's strategic human capital support contracts and information dissemination activities.

[8] www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=500047&ods_key=nsf15592
[9] www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=504793&ods_key=nsf15593
[10] www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=5733&ods_key=nsf15530
[11] www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=504924&ods_key=nsf15509
[12] NSF FY 2017 Budget Request to Congress, page Overview-16; www.nsf.gov/about/budget/fy2017/pdf/01_fy2017.pdf

Questions for the Record Submitted by
the Honorable Derek Kilmer

Advanced Computing

Question 1. Advanced computing plays an essential role in powering science and innovation across disciplines and industries. I commend the Administration for pushing advanced computing forward through the National Strategic Computing Initiative to ensure we have the next generation tools and ecosystem needed to continue world leadership. It is my understanding that the National Science Foundation plays a key role in this initiative researching new technologies, training future developers and users, and supporting computing infrastructure to enable ground breaking discoveries across science and engineering. What are your plans to ensure NSF continues to fulfill these critical roles as the US moves towards the next generation of advanced computing?

Answer: NSF plays a lead role in National Strategic Computing Initiative (NSCI) which aims to maximize the benefits of High-Performance Computing (HPC) for scientific discovery and economic competitiveness. In particular, NSF co-leads objectives 2 - 4 of the NSCI executive order which focus on scientific discovery advances, the broader HPC ecosystem for scientific discovery, and workforce development. Under NSCI, NSF will enable advances in HPC systems and maximize their benefits through deep integration of HPC cyberinfrastructure with science and engineering research along a number of key fronts: increasing coherence between the technology base used for modeling and simulation and that used for data analytics; establishing a viable path forward for HPC systems and devices in the post-Moore's Law era; and increasing the capacity, capability, and sustainability of an enduring national HPC ecosystem, including addressing foundational algorithms and software, networking technology, accessibility, workflow, and workforce development.

FY 2017 represents the initial year of NSF investment in NSCI and builds upon and expands community engagement and planning activities initiated in FY 2016. FY 2017 investments will include fundamental research and cyberinfrastructure exploration as well as initial workforce development activities. Fundamental research activities will encompass low-power computing, system resilience at extreme scales through novel algorithms and architectures, and future systems and devices in the post-Moore's Law era. These activities will engage both industry and academia along with collaboration with other federal agencies such as NIST and DOE. FY 2017 NSF activities within NSCI will also support the research, exploration, and early development of new software infrastructure for science and engineering research.

Blue Waters Supercomputer

Question 2. It is my understanding that the Blue Waters Supercomputer has enabled ground-breaking discoveries such as the recent historic LIGO gravitational wave detection. Researchers across the country depend on this critical resource to power new discoveries in diverse areas such as earthquake forecasting, materials innovation, and virus modeling. How will you ensure that this essential resource continues to be available to the U.S. science and engineering community?

Answer: The pioneering research accomplished through Blue Waters has enabled scientific discoveries in multiple disciplines including earthquake forecasting, virus modeling, geospatial analysis, and materials innovation, just to name a few examples. Solving Einstein's equations of general relativity to predict how different sources of gravitational waves would look was an

unsolved simulation problem when LIGO began. Multiple teams over many years contributed to developing new and much more advanced simulation tools that were necessary to analyze and validate the data from the interferometer. These advances in simulation required access to extremely large-scale High-Performance Computing (HPC) systems such as Blue Waters, in addition to groundbreaking research in computational astrophysics and numerical relativity, to develop the new simulation tools. This simulation capability was essential to understanding and verifying the nature of the gravitational wave detected by the LIGO interferometers. As we enter a new era of gravitational wave astrophysics, the investment in both instruments and simulations are the foundation for enabling more groundbreaking discoveries in all scientific disciplines.

During FY 2017, a plan for NSF support of large-scale HPC beyond Blue Waters will be developed within the framework of the National Strategic Computing Initiative (NSCI) and based in identified scientific frontiers. The development of this plan will be further informed by a National Academies report on "Future Directions for NSF Advanced Computing Infrastructure to support US Science and Engineering in 2017 - 2020" anticipated in FY 2016, community workshops, and NSF Advisory Committees.

Sustaining the Nation's leadership in HPC will require continued support for innovation in large-scale computational infrastructure (software, hardware, and people). This need is driven by the growing complexity and size of a broad array of traditional simulations; the expansion of the role of large-scale computation in emerging frontiers of science; and the requirement for dynamic interaction of computation with other elements of cyberinfrastructure. Through NSCI, NSF envisions a strategic investment that considers an expansive range of next-generation simulations as well as large-scale analytics. This investment will lower the barrier for tomorrow's scientists to address a broad array of discovery challenges that require large-scale computation.

WITNESSES