SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
EXAMINING THE PRESIDENT'S FISCAL YEAR 2016 BUDGET REQUEST FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
THURSDAY, MARCH 12, 2015

Questions for the Honorable Charles F. Bolden., NASA Administrator

From Senator Wicker

1. **Do you support the mission to Mars?**

   Answer. Yes.

2. **Why hasn't NASA requested funding for the 130 ton launch capability that will take us to Mars?**

   Answer. NASA's strategy for incrementally increasing the SLS lift capability is driven by the need for lift capacity in each exploration regime. Per the 2010 Authorization Act, NASA is starting with the 70mt initial capability and will advance from there to meet exploration objectives, arriving at the Mars-class 130 mt capability when it is needed. Our analyses show the 105 metric ton (mt) configuration, made possible by the addition of an Exploration Upper Stage, enables a variety of human and cargo missions in the proving ground of cis-lunar space, which are necessary to prepare for future missions to Mars. Once we are ready for missions to the vicinity of Mars, we will progress to the 130-mt configuration. NASA could not accomplish these human exploration missions effectively and efficiently without the evolving capabilities of SLS.

3. **How does the rising cost and overall shortage of helium impact NASA's propulsion testing and what cost reduction measures is NASA taking to mitigate these rising costs?**

   Answer. NASA's helium contracts were recently re-competed for FY15-19. The contract provides a fixed price for helium thru FY 2019. There was a 16 percent price increase as compared to the previous (FY10-14) contract period. This was partly due to a ~10 percent increase in FY15 Federal Crude helium pricing.

   Helium is provided by refiners thru the Federal "In-Kind" Program, where the crude helium feedstock is supplied and priced by the Bureau of Land Management (BLM) on a yearly basis. Through this program, NASA attains price stability for refined helium and maintains priority status for helium supply per the Helium Privatization Act of 1996 (now expired) and reaffirmed in the Helium Stewardship Act of 2013 (HSA).

The rising cost and overall shortage of helium has heightened NASA sensitivity to helium pricing and availability and are a catalyst for increased emphasis on reducing helium use and pursuing recovery/reclamation opportunities. Current helium reduction initiatives are described below.

Propulsion Systems

NASA is working to develop sensors to reduce over purging of hydrogen systems with helium. One example is a hydrogen vent line sensor developed by Glenn Research Center (GRC) and demonstrated at Stennis Space Center (SSC). The sensor will be tested at Kennedy Space Center (KSC) to move toward FY16 qualification for use at Pad 39 B for the Space Launch System (SLS) program.

Stennis Space Center (SSC) is NASA's primary rocket test site for large hydrogen fueled rockets such as the RS-25, which powered the Space Shuttle in the past and will power the Space Launch System (SLS) in the future; and the RS-68, which powers the Delta 4 launch vehicle. Hydrogen propulsion requires the use of helium as a purge gas and for inerting tanks and lines since it is the only gas with a boiling point lower than hydrogen. SSC routinely buys large quantities of gaseous helium for these uses to support its testing operations. In support of engine testing, NASA includes conservation measures such as changes to operational procedures and a focus on reducing leakage in systems which has resulted in reduced helium requirements over the last decade.

Kennedy Space Center (KSC) is the primary rocket launch site for the RS-25 and SLS. KSC also supports launches using the RS-68, which powers the Delta 4 launch vehicle at Cape Canaveral Air Force Station (CCAFS). Under a Small Business Innovation Research (SBIR) project KSC has investigated the potential use of Tridyne as a pressuring agent to reduce the mass of the helium required for tank pressurization in flight. KSC is looking at SLS Pad 39 B system mods to reduce helium usage for SLS. Currently one proposal is expected to result in reduction of SLS tank pulse purges between launch attempts, potentially reducing helium usage by up to 200,000 standard cubic feet (scf) or more per launch attempt.

Both KSC and SSC have an ongoing efforts to evaluate and eliminate leakage in the miles of gaseous helium (GHe) pipeline systems used to distribute GHe to users.

Balloon Program

The NASA Balloon Program is managed out of NASA's Wallops Flight Facility (WFF) and operated at the Columbia Scientific Balloon Facility (CSBF) in Palestine, TX. Normal annual operations include 3-4 campaigns with 1-9 missions per campaign. The average annual launch rate is 10 to 16 scientific missions per year

The Balloon Program Office (BPO) utilizes scientific balloons ranging in size from 4 million cubic feet (MCF) to 40 MCF. Float altitudes range from 90kft to 150kft. Helium is used as the lifting gas in the balloons. If a launch abort is necessary during the inflation process, the balloon is destroyed by releasing the helium into the atmosphere in order to protect the scientific payload or the launch crew. At the end of a successful mission, the balloon is separated from the flight train by rupturing the balloon. This action releases the helium into the atmosphere. BPO standard operations are designed to minimize helium waste. One technique employed is to transfer helium between multiple

helium ISOPAKs to maximize helium usage.

One technology interest of the BPO, which potentially would reduce the helium requirements, is the safe utilization of a lifting gas substitute, such as hydrogen. The BPO is in contact with the Technology Development Office that is monitoring development activities in this area.

NASA continues to explore advanced technologies intended to improve helium sustainability. These projects will focus on the efficient use of helium and/or alternatives to helium.

4. Is there a process in which NASA can recover helium once it is used for testing purposes?

Answer. Yes. NASA continues to pursue recovery/reclamation opportunities either through new technologies or procedural preservation efforts as described below.

KSC converts bulk liquid helium to high pressure gas for application in our space launch programs. Investigations are underway to implement a gas collection/reclamation system as part of a project to test the use of liquid helium (LHe) pumps to replace less efficient conventional gas compressors. The intent is to capture and reclaim the pump startup purges that previously would have been vented and lost to the atmosphere. If successful, the intent is to implement a similar recovery/reclamation system in the planned replacement helium Conversion Compression Facility (CCF) that will support future SLS launches as well as support all other KSC customers.

SLS conducted a review of helium use at our component vendors. VACCO produces much of NASA's cryogenic valves and disconnects. Early in the Space Launch System (SLS) program NASA had a helium reclamation system installed at VACCO to reduce the amount of helium used to test and checkout components during development. The

system has greatly reduced the helium necessary for VACCO and paid for itself several times over. We have also loaned out the system to other government agencies.

- VACCO is currently forecasting a 70 percent to 85 percent He Reclamation Savings (dependent on a number of specific variables associated with individual tests)
- The initial program projections for Helium Supply cost were ~$5.3M. However, today the current forecast for helium supply costs is just over $1M due to the reclamation success.

NASA has been pursuing helium recovery and reclamation for several years. Through the Small Business Technology Transfer (STTR) Program, two particular projects have been delivered which demonstrated the ability to separate helium from a hydrogen/helium gas mixture. The recovered helium meets the stringent purity requirements for reuse. Both systems use fuel cell technology to extract pure hydrogen from a mixed hydrogen/helium gas mixture, leaving nearly pure helium.

The first project was designed by Sierra Lobo, Inc (SLI). SLI delivered a system that was installed and tested at NASA Stennis' E-3 facility. The system demonstrated the ability to output high quality helium from a hydrogen/helium gas mixture. The helium/hydrogen gas mixture was collected, helium extracted and recovered. Below is a picture of a system delivered by Sierra Lobo, Inc.

The second successful test was conducted by Sustainable Innovations, Inc. (SII) in support of SSC. SII delivered a prototype unit in 2014 that successfully demonstrated the ability to capture, separate and compress helium from a mixture derived from test operations. This system featured a subsystem that captured the vented hydrogen and helium gas mixture, an electrochemical separation subsystem that effectively purified both hydrogen and helium streams, and a compression subsystem that permitted high pressure gas delivery. Each subsystem performed well in project tests and the subsystems were shown to integrate seamlessly.

The ability to effectively recover and reclaim helium is heavily dependent on how the original helium is used and the quantities involved. Commercial reclamation systems do exist but are typically utilized in closed systems and are often limited by their throughput, typically requiring the use of collection systems to allow batch processing of any contaminated helium.

With the largest NASA helium uses occurring during launch operations and engine testing, the challenge for NASA is multi-faceted. SSC in partnership with KSC has an FY15 Small Business Innovative Research (SBIR) initiative that seeks to improve upon the demonstrated technology or develop new alternative cryogenic gas separation technology. Additional development is needed to increase the efficiency of the recovery process, capture large amounts of mixed gases, and provide real-time solid state sensor technologies for characterizing constituent gases. Specific areas of interest includes the following technologies:

- enhanced membrane technologies including Proton Exchange Membrane (PEM) fuel cells that increase the efficiency, recovery production rate or life span of fuel cell based separation technologies;
- development of alternative cryogenic gas separation technologies;
- technologies for the rapid capture and storage of high volumes of mixed cryogenic gases;
- development of zero trapped gas system technologies to improve purge effectiveness; and
- development of real-time, solid state sensor technologies for monitoring the current state of the system concentration levels and helium/nitrogen purge process effectively (e.g., hydrogen, oxygen, water vapor content, etc.).

For NASA's Balloon Program Office (BPO), helium is the lifting gas (i.e., the propellant) for BPO missions. Just as other propellants are consumed in the mission, helium is consumed in BPO missions. It is not considered feasible to recapture the helium at the end of a stratospheric balloon mission, since the termination technique requires the rupture of the balloon envelope to bring the scientific instrument back to earth safely.

In summary, NASA continues to investigate opportunities to recover and collect

contaminated launch and engine test helium especially for smaller GHe usage quantities or program tests that lend themselves to closed loop systems.

5. **From a cost benefit standpoint, assuming helium cost will only continue to rise, would it not make sense for NASA to research and develop propulsion test technology to reclaim and store helium for future use?**

   Answer. NASA continues to pursue ways to reduce and/or reuse helium. Some of the challenges that must be overcome include scale-up of the technology to allow large volumes of mixed gases to be processed and capture of mixed purge gases during test operations without affecting performance of the rocket engine system. The programmatic challenge is the upfront cost to deploy the technology, the scale on which these systems can operate, and the limited number of areas in which NASA could actually use it (primarily for hydrogen transfer line and tank inerting operations). Helium would have to become considerably more expensive (or supply more uncertain) to justify a return-on-investment case, or additional funding would be required just based on the principle that conservation of helium is strategically important.

   Today helium is the highest value gas used in propulsion testing. NASA's current supply from our "In-Kind" Program managed by the BLM offers price stability and priority of supply under the Federal Program. The increased costs of helium and potential impacts particularly when the Federal Helium Reserve closes, makes the helium conversation more important from a product cost and future supply aspect. The challenge is how to do it efficiently and in a cost effective manner.

6. **Why has NASA steered ocean science funding away from Stennis Space Center?**

   Answer. NASA uses the annual omnibus solicitation, Research Opportunities in Space and Earth Sciences (ROSES) to compete program elements in the Science Mission Directorate, including oceans. These federal opportunities in ROSES are open to all eligible domestic institutions, including Stennis Space Center. Awards to successful institutions are made following the NASA peer review process.

7. **No ROSES grants were awarded to the Gulf of Mexico Initiative in 2014. Is NASA abandoning the Gulf of Mexico Initiative?**

   Answer. The Gulf of Mexico is an important region to NASA and the nation. In the aftermath of Hurricanes Katrina and Rita, NASA's Applied Sciences Program undertook the Gulf of Mexico Initiative (GOMI) focused on the Gulf region to help build capabilities in applying Earth science data. Through two special competitive grant solicitations, NASA's Applied Sciences Program sponsored 48 projects to improve the use of Earth observations to support water resources, health, disasters, agriculture, and ecosystem management in the Gulf region.

   With the completion of the last GOMI Project in January 2013, the need for a dedicated, capacity-building effort focused on the Gulf has been addressed. Other competitive research programs in NASA's Applied Sciences Program and the broader Earth Science Division have and will continue to encompass coastal management issues and the Gulf region through peer-reviewed solicitations.

From Senator Blunt

1. **Your budget request for NASA's Science Mission Directorate (SMD) is $5.28 billion – roughly 28 percent of the entire NASA budget request of $18.53 billion.**

   Moreover, this request for the Science Mission allocates the largest proportion of funding -- $1.95 billion -- to the Earth Science account. The Earth Science program includes several accounts associated with climate change research.

   In our current financial environment, where we have enacted budget caps on discretionary spending, why is NASA spending over 10 percent of its total budget on the Science Mission and climate change research?

   Answer. The National Aeronautics and Space Act, as amended [P.L. 85-568, 72 Stat., 426], states the first objective for NASA is to contribute to "The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space." Thus, Earth Science has been part of NASA's core mission. since NASA's early years. The President's FY 2016 request for Earth Science is slightly over 10 percent of the total agency request. This is not much different from actual appropriations for the last four fiscal years (FY 2012-2015), which average 10.0 percent, ranging from 9.8 percent (FY 2013) to 10.3 percent (FY 2014).

   Within the overall NASA Earth Science activity, climate change research remains an important – although not the sole - element of Earth science study. Indeed, measurements from many NASA Earth observing research satellites are used routinely by other federal agencies to improve their operational products and forecasts. For example, measurements from NASA's Global Precipitation Measurement (GPM) Core Observatory/GPM constellation, Moderate Resolution Imaging Spectroradiometer (MODIS), and the Jason-2 ocean altimeter mission are used routinely by NOAA and the DoD weather services to improve global and regional weather forecasts and extreme event predictions. Soil moisture data from GPM, Gravity Recovery and Climate Experiment (GRACE), and the Soil Moisture Active-Passive (SMAP) mission are used routinely by NOAA and FEMA to produce daily flood hazard forecasts and drought monitoring products. Data from the NASA MODIS instruments are used by civil and DoD agencies for a variety of environmental forecasts including dust storm and visibility predictions.

   NASA collaborates closely with the other federal agencies involved in climate research, through mechanisms such as the legislatively-mandated US Global Change Research Program. However, NASA is the only civil federal organization that can procure, develop, and launch Earth monitoring spacecraft that provide critical space-based observations to support research, and then conduct the scientific research they bring forward. NASA provides sustained and experimental observations, and focuses on space-based platforms to advance research, technology development, and national capabilities. These responsibilities are described in the National Plan for Civil Earth Observations. The results from these activities are documented in peer-reviewed literature, and the resulting information and knowledge are made routinely and widely available to scientists, managers, and citizens throughout the Nation and the world. NASA's Earth research

covers diverse topics, both long- and short-term phenomena and processes, including those associated with droughts, floods, fires, air pollution, land cover/land use change, oceans, and polar ice.

2. **The administration's budget request proposes to cut funding for the heavy-lift Space Launch System (SLS) rocket by $343 million. It also proposes to cut the Orion crew capsule by nearly $98 million. There is concern that these cuts may prevent NASA from meeting its schedule to test Orion and SLS, and its goal of a manned SLS/Orion mission by 2021.**

   Given all this, how does it make sense to allocate $1.95 billion to Earth Sciences and climate change research while underfunding SLS and Orion?

   Answer. The FY 2016 President's Budget Request is consistent with the outyear profile proposed in the FY 2015 Budget and provides the funding level needed to keep SLS, Orion, and Exploration Ground System (EGS) on track for the first integrated launch of Exploration Mission -1 (EM-1). We have identified our Agency Baseline Commitment for the SLS and EGS which supports 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. The integrated launch date for EM-1 is to be determined after all three programs complete their Critical Design Reviews (CDRs). The integrated launch date for EM-2 will be set following the EM-1 mission.

   While maintaining planned funding levels for SLS and Orion, the FY 2016 Request provides Earth Science with funding to address the priorities set forth in the 2007 Earth Science decadal survey.

   <u>Follow Up</u>: How does climate change research help ensure American leadership in deep space exploration?

   Answer. NASA has since 1958 been charged with expanding human knowledge of the Earth and of phenomena in the atmosphere. As part of this responsibility, climate change research produces valuable and executable scientific knowledge that is actively being applied by the international community, policy makers, and industry to better understand the challenges posed by climate change, which in turn improves our Nation's posture in addressing these challenges now and into the future. We conduct climate change research for those reasons rather than to support deep space exploration, but studying climate change improves our ability to address and plan for its societal and economic impacts, which in turn will help us maintain our global leadership in space for science and exploration.

   <u>Follow Up</u>: How does climate change research assist in the development, construction, and testing of SLS and Orion?

   Answer. NASA studies climate for many reasons. Any benefits to the development and testing of SLS and Orion are secondary. However, many NASA Centers and assets reside in vulnerable locations. The Johnson Space Center, Kennedy Space Center, Stennis Space Center, Michoud Assembly Facility, Wallops Flight Facility, and Jet Propulsion Laboratory have significant involvement in NASA's launch and rocket

programs, and each are vulnerable to climate-induced changes. For example, Johnson, Kennedy, Stennis, Michoud, and Wallops are vulnerable to sea level changes and climate-induced upticks in extreme weather conditions, such as hurricanes and tropical storms. Meanwhile, JPL is vulnerable to geohazards such as landslides, earthquakes, wildfires, and even water shortages. NASA assets closely monitor changes in the climate that create these increasing vulnerabilities, to produce analyzable data to address these vulnerabilities. For example, NASA's Applied Science Program is dedicated to helping public and private organizations apply data from NASA's Earth-observing satellites and related scientific findings in their decision-making activities, to improve the quality of life and strengthen the economy. Both SLS and Orion will make prominent use of NASA Centers, some of which are vulnerable to changing environmental conditions. Our study of these changes will ultimately help us ensure NASA assets are as secure as possible.

Senator Rubio

1. **The people, facilities and capabilities of NASA at Kennedy Space Center are one of Florida's most treasured and iconic assets, and I look forward to their participation in future Exploration missions.**

   However, as a new commercial space industry and marketplace begins to take root across the country and abroad, I am concerned the existing federal regulations and requirements at KSC will unfairly disadvantage the State of Florida from competing in these new opportunities.

   How are you now working with the State to help eliminate federal impediments to a more favorable commercial operating environment? What steps are you taking to implement the expedited transfer of unneeded NASA assets the State's spaceport authority may be willing to take over and operate in partnership with commercial users?"

   Answer. NASA has taken a number of actions to significantly reduce impediments to commercial operations. One example is the revision of safety requirements for commercial operators. Under the new rules, commercial entities operating within their own facilities or facilities that they have leased from NASA, need only follow OSHA and other relevant federal safety and environmental requirements. Another initiative is related to the development of new commercial facilities on KSC. Such facilities may be constructed using Florida State building codes rather than the sometimes more restrictive NASA standards.

   NASA has worked with both the State of Florida and commercial entities to provide a number of assets for use by the commercial space industry. Specifically, the State of Florida already has a Use Permit to operate the Orbiter Processing Facility 3 (OPF3) and associated Processing Control Center (PCC) which will be used by a commercial space industry company. We have also leased Launch Complex 39A to a commercial space launch provider for their use. We are in the final phases of providing the use of the Shuttle Landing Facility and associated land around the facility for a total of

approximately 4000 acres to the State of Florida to develop commercial operations.

2. **Competition is a key to controlling costs over the long-term as well as to improving the level of safety. Do you agree with this statement?**

Answer. NASA agrees that competition is one key to controlling costs and helping to improve the level of safety. For this reason, supporting multiple competitors in our commercial cargo and crew programs is considered critical.

3. **In your opinion, what is the single greatest threat facing American access to space? And what is the best option for overcoming that threat?**

Answer. Access to space for NASA should be considered in three categories:

- crewed missions to Earth orbit (i.e., Commercial Crew Program to transport crews to and from the International Space Station [ISS]);
- uncrewed, expendable launch vehicles putting NASA's and the civil sector's satellites in Earth orbit and robotic planetary probes in space; and
- heavy lift launches beyond low Earth orbit for both crew and cargo (i.e., NASA's Space Launch System).

The greatest threat facing American access to space for crewed missions to Earth orbit is the current lack of capability to launch astronauts to orbit from U.S. soil. NASA's Commercial Crew Program is our answer to that threat, and we are well on our way with the progress our two commercial partners, Boeing and SpaceX, are making. The best way to secure this capability is to fully fund the FY 2016 President's Budget Request, which is required to keep NASA and both of its commercial partners on track to achieve first flights of these new crewed vehicles to ISS by the end of 2017.

For uncrewed expendable launch vehicles, NASA has a robust mechanism through its Launch Services Program to acquire and manage such services for the launch of NASA's satellites and planetary probes. NASA acquires these launch services on a competitive basis, with the vendors responsible to sustain and mature their systems and to deal with supply problems, including engines for their vehicles. The ISS cargo resupply endeavor managed under Commercial Resupply Services contracts has resulted in new medium class launch capabilities for science missions. NASA is evaluating the impact of the recent loss of SpaceX-7. The key for access to space in this category is encouraging and promoting an environment of innovation and competition for our U.S. commercial launch service providers.

For heavy-lift launch capability for crews and cargo beyond low Earth orbit, NASA is progressing well in the development of the Space Launch System, and its planning its evolution consistent with the 2010 NASA Authorization Act. Careful management of this program to both achieve a timely, successful first flight and an affordable production and operations cost for future flights is a major focus for NASA.

4. **I too often hear in Florida about challenges in launching from the Cape, and I fear companies may choose to launch elsewhere because of those challenges. What issues**

prevent a completely independent commercial launch capability in Florida, and what is NASA doing to overcome these issues?

Answer. Consistent with the 2010 National Space Policy and the 2013 National Space Transportation Policy, NASA leadership has been seeking to increase commercial utilization of the Kennedy Space Center (KSC) resources and to allow the commercial sector to demonstrate competitive and innovative approaches, to ultimately reduce space exploration costs for several years. In FY 2011, NASA began the 21st Century Space Launch Complex (21CSLC) initiative to support launch infrastructure, enable future exploration of the solar system, as well as new commercial opportunities in low Earth orbit. Its primary purpose is to modernize and transform the Florida launch and range complex at Kennedy Space Center (KSC), Cape Canaveral Air Force Station (CCAFS), and Wallops Flight Facility (WFF) into a more robust launch capability that could support multiple users. Beneficiaries of this activity included current and future NASA programs, other U.S. Government agencies, and commercial industry.

The KSC has developed a multi-use, operational approach with the goal to accommodate commercial launch and reentry activity from KSC property while preserving public and property safety, and minimizing Governmental burden. KSC first developed a Future Development Concept with the broader national space community, which led to a KSC Master Plan that provides a flexible framework for evolving to a multi-user spaceport. This plan, available at: http://masterplan.ksc.nasa.gov/, describes how KSC will continue to transform over the next 20 years as a multi-user spaceport supporting government, commercial and other space launch users and providers. This 20-year plan describes KSC's future state, along with the supporting business focused implementation and operating framework necessary to enable this transformation.

Given the phase out of Space Shuttle operations, KSC recognized the need to safely manage a multi-use spaceport containing new NASA programs and commercial activity. KSC's current commercial safety policy is a set of requirements which ensures that NASA KSC is exercising reasonable diligence to protect the public and Center personnel, and safeguards the success of NASA missions and operations, while enabling commercial activities to the maximum possible extent. This supports KSC's commitment to safety while providing commercial partner autonomy in managing their operations.

One of the challenges in planning for Commercial Operations on KSC property has been flexibility in Range Flight Safety Services for launch operations. NASA is working with the Air Force (including the 45th Space Wing) and the Federal Aviation Administration (FAA) to define and implement the steps necessary to accommodate commercially-provided range flight safety services options for the commercial space industry when they launch within the Eastern Range (including from KSC property) under an FAA license.