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NASA ADVISORY COUNCIL

August 29-30, 2018

NASA Ames Research Center
Mountain View, CA

MEETING MINUTES

P. Diane Rausch
Executive Director

Lester L. Lyles
Chair

NASA ADVISORY COUNCIL

NASA Ames Research Center
NASA Ames Conference Center
Building 3, Ballroom
Mountain View, CA

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Meeting Report prepared by
Joan M. Zimmermann, Zantech IT, Inc.

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Call to Order, Announcements

NASA Advisory Council (NAC; or Council) Executive Director, Ms. P. Diane Rausch, brought the second NAC meeting of 2018 to order, and welcomed Council members and attendees. She described the rules that govern the NAC as a Federal advisory committee, established under the Federal Advisory Committee Act (FACA). She noted that the meeting is open to the public and that formal meeting minutes would be taken and posted to the NASA website, www.nasa.gov/offices/nac. Ms. Rausch informed members, attendees, and speakers that all presentations and comments would be part of the public record.

Opening Remarks by NAC Chair

General Lester L. Lyles, Chair of the NASA Advisory Council (NAC or Council), opened the public portion of the meeting, reviewed the afternoon's agenda, and led introductions around the table. He gave a brief history of the NAC, founded in 1977 as the advisory support arm to the Administrator, covering a full portfolio of NASA activities. He expressed his pride at being part of a large group with a wide breadth of experience, and introduced Dr. Eugene Tu, Director of the NASA Ames Research Center.

Welcome to NASA Ames Research Center

Dr. Eugene Tu, Director of NASA Ames Research Center (ARC), provided an overview of the center, first briefly describing his 34-year career with NASA, and background in aerospace engineering. He emphasized the importance of ARC's placement in the innovative ecosystem of Silicon Valley, which in itself is an inspiration to NASA that has often created one-of-a-kind instruments and missions. In this competitive environment, many employees at ARC go in and out of industry, garnering valuable experience that can in turn be infused back into NASA. ARC has a long history, and it housed one of the early National Advisory Committee for Aeronautics (NACA) laboratories, NACA being the precursor organization to NASA. ARC features a large hangar built in 1933, one of the largest free-standing structures on Earth. ARC has been involved in the three major evolutionary phases of NASA: aeronautics and aerodynamics; space and science missions (e.g., Voyager, Galileo, Viking); and is now in its third phase as part of the modern growth in information sciences, autonomous technologies, and high-end computing (HEC). The Center has 2600 employees, of which 1200 are civil servants, and 1400 are contractors. ARC was once part of the Moffett Field Naval Air Station. NASA has since acquired the property and expanded it, and is now leasing ARC space as a research park, which houses many interests in both the private sector and academia. Carnegie-Mellon University and Singularity University are housed at ARC. In the near future, the U.S. Geological Survey (USGS) will be moving to ARC as well, creating even more opportunities for science. ARC operates on a $900M annual budget, and receives about $150M per year in reimbursable funding. ARC will celebrate its 80th anniversary next year.

ARC comprises eight core competencies: air traffic management; entry, descent and landing (EDL) systems; advanced computing and information technology (IT) systems; intelligent/adaptive systems; astrobiology and life science; space and Earth sciences; aerosciences; and cost-effective space missions. ARC touches every part of the

Agency, thereby creating the opportunity to foster cross-cutting research and technology development in areas such as Aeronautics. The Center houses key facilities, including the largest wind tunnel in the world, which is leased by the U.S. Air Force and used by NASA as necessary. The facility is used to test Mars EDL parachutes and components of the Space Launch System (SLS). ARC has the Agency's only arc jet complex, used for EDL and thermal protection system (TPS) testing. The heat shield for the Dragon module, as just one example, was developed at ARC. ARC has much complementarity with Department of Defense (DoD) activities, and uses the DoD's Washington, DC, facilities when needed. ARC houses a range complex, and human-in-the-loop (HIL) simulators to advance autonomous systems. ARC also houses the Pleiades computer complex, which supports HEC modeling, and quantum computing and annealing. Partnerships at ARC include interagency, international, and private sector pursuits. ARC's Virtual institutes include Astrobiology, Solar System Exploration, Aeronautics, and Small Satellite Research.

Dr. Tu concluded his remarks by introducing NASA's thirteenth Administrator, the Honorable James Bridenstine.

Remarks by NASA Administrator

NASA Administrator James Bridenstine addressed the NAC, indicating that it was the first time such an address had been aired by NASA TV, in the hope and expectation that more United States citizens would learn about what NASA brings to the country. The Administrator stated that he regarded NASA Ames as a spectacular NASA Center, as are all NASA Centers, and he thanked General Lyles for chairing the critically important NAC meeting. The NAC holds an important place in NASA history: NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), was an advisory body going back 100 years, and helped establish the United States as a preeminent air-faring and space-faring entity. The NAC is helping the U.S. keep its technological edge in the world. Mr. Bridenstine acknowledged the impressive expertise of the Council members, commenting that NASA generally accepts the NAC recommendations.

NASA at present is gearing up to carry out three Space Policy Directives (SPDs), the first of which, SPD-1, is to return to the Moon. This Directive has been heard before, in the 1980s, in the early 2000s, and has been beset by distractions and budget changes. In SPD-1, there are some differences. This SPD specifically says we are going to the Moon sustainably, and not simply doing "flags and footprints" again. This time we are going to go to stay, starting by taking advantage of capabilities that did not exist a decade ago, and using these capabilities to develop a sustainable architecture, leveraging the advantages of international and commercial partners. There are re-usable rockets today, which did not exist in the Apollo era, which are driving down costs and increasing access to space. A sustainable architecture will include reusable tugs, reusable landers, long-lived space stations around the Moon, and in-situ resource utilization (ISRU) at the Moon. These features will allow sustainability. In 2008, India discovered water ice on the Moon, particularly at the lunar poles. Water ice represents life support: water to drink, oxygen to breathe, and rocket fuel for engines. To allow us to get access to more parts of the Moon than ever before, the Deep Space Gateway (DSG), in contrast to an International Space Station (ISS), will be maneuverable via solar electric propulsion (SEP) technology, with use of minimal fuel. The Gateway can also be to move to nearby Lagrange points. The DSG architecture needs to be public, interoperable, enabling other entities to build their own landers. The last piece of the Gateway concept is to retire risk, prove ISRU, and replicate these abilities at Mars. There could be trillions of dollars of platinum on the Moon, as well as rare earth metals (the remnants of asteroid impacts), the latter of which could be sitting pristinely on the Moon. NASA needs to actively work to ensure the United States finds these resources, and not someone else. We also need to better understand the effects of space habitation, microgravity effects, and radiation effects on physiology. Although some understanding of these physiological factors has been acquired from ISS research, NASA will need to extend this knowledge before humans can be safely sent on long Mars excursions.

SPD-2 focuses on the regulatory environment. More things are happening in space than ever before. Some capital is going overseas due to regulatory constraints in the U.S. We want capital flowing to the U.S., not from the U.S. NASA can take advantage of nontraditional space activities such as robotic servicing of satellites, mining asteroids, and mining on the Moon. The Directive places this activity at the Department of Commerce, in an effort to keep our commercial partners here in the United States.

SPD-3 establishes a coordination committee to build situational awareness of space traffic management in an effort to deal with the growing problem of space debris. NASA has a role to play in developing technologies to preserve

the space environment for future generations. It is estimated that every three to five years, there will be an Iridium-type accident, caused by trackable debris of 10 cm or larger. In 2007, a nation launched a direct ascent and knocked out its own satellite, producing debris we are still dealing with today. There is much talent to harvest in the U.S., in academia and in virtual institutes. While the regulatory authority will be housed in the Department of Commerce, NASA will build the capabilities to track space debris.

In sum, NASA is going back to the Moon, and will be exploring non-traditional space activities, while streamlining regulations for space situational awareness and air traffic management. NASA is looking to the NAC to give the Agency the best advice possible, to help continue American preeminence in space and aeronautics.

General Lyles asked Mr. Bridenstine how the NAC might help NASA get the word out on its programs on a more compelling basis. Mr. Bridenstine noted that he had frequently heard that question at Town Hall meetings; and that the bottom line was that he wants to get the word out on how important space is to everyone in the U.S.. He pointed that virtually all of the ways in which we now communicate were made possible because NASA blazed the communications trail. NASA retired risks, made the technologies public, and enabled humanity to use these technologies to benefit the world. Mr. Bridenstine related a story of meeting a farmer in Nebraska, who had asked him what he did. Mr. Bridenstine had responded to the gentleman by relating the numerous ways in which NASA technology has aided farmers in planting, harvesting, and allocating water effectively for crop growth; amazing developments which enables farmers to feed more people. NASA has revolutionized the way we understand weather: 80% of the data that informs weather forecasting is from NASA, given over operationally to another U.S. Government agency, the National Oceanic and Atmospheric Administration (NOAA). NASA research and technology is critical to national security, disaster relief, global positioning system (GPS) timing signals for banking transactions, data flow, and the power grid. All of these capabilities are available to the American public thanks to NASA. NASA technologies have elevated living conditions for the entire world. Mr. Bridenstine indicated that he is the first NASA Administrator to use Twitter, trying to reach the new generation and more of the world. Social media is a big piece of the effort, and NASA can get the message out in many ways.

In some cases, the NASA message has been constrained by regulations and laws. Mr. Bridenstine remarked that he would like to see kids growing up wanting to be a NASA astronaut or scientist. To that end, perhaps it is time to embed NASA in the American culture by doing such things as putting astronaut photos on cereal boxes. In order to commercialize low-Earth orbit (LEO), NASA must figure out unique ways to exploit it. In this context, Mr. Bridenstine announced that he had established a new NAC committee, the Regulatory and Policy Committee, to which he had appointed Mr. Michael Gold as Chair. This new committee will explore how to maximize NASA exposure, commercialize NASA resources, and explore some potentially provocative ideas. Mr. Gold thanked General Lyles and Mr. Bridenstine and offered some introductory remarks to the NAC.

Mr. Gold noted that NASA is famous for overcoming herculean challenges, but conquering policy and regulatory hurdles is just as important. His new committee aims to attack barriers to these goals. There is a wide array of topics to explore in the matter of ISS and private sector LEO operations, and NASA must help to establish a robust business case for LEO. American astronauts should be given the freedom to seek endorsements and promote themselves with private companies and media. Mr. Bridenstine interjected that the U.S. is currently experiencing a shortage in military aviation because commercial pilots make more money. Mr. Gold remarked that the nation should fully leverage its capabilities in space. One consideration has been utilizing branding on spacecraft. Mr. Bridenstine noted that potentially, it is possible for NASA to offset some of its costs by selling naming rights for spacecraft and rockets. Mr. Gold agreed, adding that NASA should act as a catalyst for the private sector by utilizing excess seats, habitats, and volumes in space. The U.S. must not saddle its children with a space platform gap. The new NAC Regulatory and Policy Committee will provide advice on expanding ISS contracts. For instance, the International Traffic in Arms Regulations (ITAR) has been a barrier to launches; the U.S. must ensure that commercial development is not held back. The new Regulatory and Policy Committee will also review space traffic management, and regulations that govern the contamination of the Moon and Mars. The intent of this new committee is to "achieve escape velocity from red tape."

Mr. Bridenstine addressed the issue of commercializing LEO in such a way that will prevent future gaps. NASA astronauts are currently prohibited from doing some experiments on ISS due to intellectual property (IP) issues: if our commercial crew partners have seven seats, how do we offset these costs? It might be possible to form industries around the microgravity environment at ISS (e.g., pharmaceuticals, using adult stem cells to 3D-print human

organs). The Regulatory and Policy Committee will ask the tough and provocative questions. General Lyles commented that he believed that "the stars were aligned" for making progress on this front, as the National Space Council and its Users' Advisory Group (UAG) were also tackling regulatory issues. Mr. Bridenstine commented that past National Space Councils have not always been effective, but that he expected the current one to be different. DoD, National Intelligence, the Departments of Transportation and Commerce, and NOAA are also involved in space; all the heads serve on the National Space Council, which is chaired by Vice President Pence and is actively engaged and personally interested. NASA has great bipartisan support in Congress, and the latest budget has increased NASA's budget by $1.7B. Mr. Bridenstine said he would work to ensure that NASA remains apolitical and bipartisan, and focused on things that can unite the country. Dr. Aimee Kennedy asked for Mr. Bridenstine's thoughts on the role of NASA in preparing the Science, Technology, Engineering and Mathematics (STEM) workforce of the future. Mr. Bridenstine noted that he had once headed the Tulsa Air and Space Museum, thus he had seen in very immediate ways how NASA can impact the lives of children. He then related his own personal experience at a summer camp where he was able to get hands-on experience with wind tunnels and aerodynamics research, an experience that ultimately guided him toward his career in aviation. He noted that NASA technology enabled the advanced engineering techniques that improved the flight controls of the X-29, largely through NASA development of composite materials and flight control computer capabilities. NASA must do stunning things, which is why he believed so strongly in NASA's current X-plane program. Advances of this kind is what inspires and excites kids. He remains a big advocate of NASA's STEM mission. Everyone of a certain age remembers the Apollo 11 Moon landing in 1969. NASA needs more stunning achievements of this kind and must ensure it communicates its achievements to the world.

Dr. Meenakshi Wadhwa commented that there is incredible science that can be implemented through SPD-1, and asked how the Administrator would prioritize this science. Mr. Bridenstine responded by assuring the NAC that he would follow the advice of the National Academies' Decadal Surveys for the various disciplines to ensure that NASA dispassionately follows the consensus of the science community. NASA needs to think in trans-disciplinary ways about what science is at the Moon. There is much science at the Moon that is yet to be understood. NASA is considering forming a NAC committee or subcommittee of the Science Committee that is focused on science at the Moon, specifically, to optimize synergies. Dr. Thomas Zurbuchen, NASA Associate Administrator for the Science Mission Directorate (SMD), noted that he believed that the Moon is worthy of exploration in and of itself, particularly with respect to questions about the lunar water cycle. The surface of Moon is nearby, relatively speaking, and it can provide answers to questions for many disciplines in SMD. The far side of the Moon provides a quiet window in the electromagnetic spectrum, for instance, which would enable the placement of very-low-frequency radio arrays for astrophysics research. SMD will use the Decadal Surveys to prioritize lunar science and will also consider the guidance that springs from the larger science community. Mr. William Gerstenmaier, Associate Administrator for the Human Exploration and Operations Mission Directorate (HEOMD), noted that he had just attended a joint session of the NAC Human Exploration and Operation Committee and NAC Science Committee, and reported a good exchange between the two, resulting in important joint findings and recommendations. He found the intersections between the disciplines to be a rich environment, which would enable novel progress in both.

Mr. John Borghese, Chair of the NAC Aeronautics Committee, welcomed Mr. Bridenstine's remarks on the importance of aeronautics, and asked him to comment on current aeronautics policy. Citing NASA's Low Boom Flight Demonstrator (LBFD), the Administrator stressed the importance of minimizing sonic boom, and flying faster in general. In addition, he remarked that he had fully supported the X-37 Maxwell project as the first all-electric aircraft designed to carry humans and cargo. He reiterated that the idea is for NASA to retire risk and then allow companies to commercialize new aircraft to help maintain the country's edge in aviation technology and aviation export. It is critical to work hard to maintain that leadership, and to commercialize with an eye to export capabilities. Mr. Miles O'Brien, NAC member, offered the Administrator kudos for deciding to televise the current NAC session on NASA TV for the first time. Referring to the Earth Science enterprise at NASA, and in light of modern efforts to deny climate change, Mr. O'Brien asked how these conditions might affect resources for Earth Science. Mr. Bridenstine pointed out that the latest President's Budget request for NASA's Earth Science program is larger than three previous years and is actually healthy. He described his goal as NASA Administrator is to follow the guidance of the Earth Science Decadal Survey. He related his history as a member of the House Armed Services Committee, wherein he had supported an amendment recognizing climate change as it pertains to the national security posture. He said he had also supported the Earth Science Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission as a member of Congress. He acknowledged that carbon dioxide is a greenhouse gas, and that humans in fact are in part

responsible for the warming of the climate. There is more to understand about the biosphere and lithosphere, and to determine whether these changes are stabilizing or destabilizing. What is known about the Earth System is thanks to NASA. NASA cannot prescribe the solution, but it can do dispassionate science, get the data and share it in a robust way. At the time of the very creation of NASA, there was a mission to understand Earth. Mr. Bridenstine promised to take the NAC advice to heart. General Lyles thanked the NASA Administrator for his comments, and expressed his excitement at having Mr. Bridenstine at the helm of NASA.

NASA Exploration Update

Mr. William Gerstenmaier, Associate Administrator for the Human Exploration and Operations Mission Directorate (HEOMD), briefed the NAC. At HEOMD, the surface of the Moon is now playing a key role. With the support of SPD-1, HEOMD is committed to creating an innovative and sustainable presence in cis-lunar space. This effort is not just for moving humans to other Solar System destinations; it is also meant to ultimately benefit society. Mr. Gerstenmaier stated that NASA already has authority on the books that is perhaps misinterpreted, but recognized that the commercial sector wants some assurance of regulatory stability, to push forward with projects in low-Earth orbit. Mr. Gold complimented Mr. Gerstenmaier on his successful and ongoing communications posture with the Power Propulsion Element (PPE) community, via his recent Broad Area Announcement (BAA). Mr. Bridenstine interjected that he supported Mr. Gerstenmaier's approach of querying industry on their concepts for PPE, in place of directing industry activity. Mr. Gerstenmaier commented that the commercial satellite industry already has robust, long-lived buses that are suitable for the PPE component of the Deep Space Gateway, and it seemed appropriate to remove NASA requirements to adapt their proven and reliable technology. He added that NASA's legal and contracting teams also did an excellent job in dealing with the deviations, essentially taking a strict contract and smoothing it out. He felt that NASA was embracing a new way of doing business. General Lyles asked Mr. Gerstenmaier about any policy issues facing HEOMD. Mr. Gerstenmaier noted that he would be coordinating this information in preparation for an Agency panel presentation, and would provide these materials to the NAC.

Mr. Bridenstine briefly interrupted the session to announce that space pioneer Dr. Paul Spudis had just passed away. He outlined many of Dr. Spudis's achievements, including investigations that led to the discovery of water ice on the Moon. The NAC observed a moment of silence for Dr. Spudis.

Mr. Gerstenmaier resumed his presentation, addressing aspects of SPD-3 and the need to start thinking about the vicinity of the Moon, how to reduce the debris footprint around the Moon, and how to reduce contamination on ISS. NASA needs to re-examine current models to ensure that it will not contaminate instruments at the Deep Space Gateway. In HEOMD, NASA's job is to remove risk, and do things that are difficult that don't necessarily make business sense. To this end, NASA can buy services, create markets, and ultimately lower risk to the private sector. Industry can take NASA's advances and generate revenue from them, while NASA can go back and do the next big thing. NASA cannot create markets, but it can expose the unique applications of LEO and present them to companies. The commercial sector's role is to be adapters and adopters. General Lyles cited the gap between exploration and development, known in the business world as the "valley of death." He asked what HEOMD considered as the technology readiness level (TRL) necessary for the handoff to industry. Mr. Gerstenmaier responded that the matter involved not just a TRL, but also a business readiness level. With the completion of 13 recent studies, NASA will hear back from various companies on what that looks like. In return, NASA will be offering subsidized launch costs, power and data on ISS, and crew time. NASA is eager to see what the industry response is. Mr. Borghese commented that ISS is already adding value in robotics and automation, and asked how HEO intended to use these technologies to prepare for humans in space. Mr. Gerstenmaier indicated that the placement of radiation monitors on Mars rovers and spacecraft had greatly informed understanding of the radiation environment humans may encounter in space and on the surface of Mars. Robotics techniques are now being used to loosen bolts on batteries on ISS, which has greatly reduced the need for human extravehicular activity (EVA) time. Remote power controllers can now be changed from the ground. The Deep Space Gateway will be a good place for extending robotic operations even further. There is plenty of relevant technology to leverage in the self-driving car industry, as well as from advances in machine learning and artificial intelligence.

Mr. Gerstenmaier reviewed the strategic principles governing sustainable exploration: fiscal realism; scientific exploration; technology pull and push; gradual build-up of capability; architecture openness and resilience; commercial partnership; global collaboration and leadership; and continuity of human spaceflight. The initial approach will be to use robotic spacecraft to explore environments that will later have humans. In terms of

technology pull and push, the Space Technology Mission Directorate (STMD) develops technologies, while HEOMD pulls the technologies through the gap, and offers it to the industry. All hardware built should feed forward to Moon/Mars exploration, with no one-offs. In an open and resilient architecture, HEOMD can adapt nuclear propulsion, or advances in any areas where industry has made inroads. NASA continues to seek global collaboration in order to ensure the continuity of human spaceflight.

HEOMD is using the ISS as a springboard for the development of voluntary interoperability standards, and is in the process of getting global feedback on these standards. There is already an international docking standard in place, and there are standards being established in other avionics areas, that will allow small space agencies to engage with NASA more easily. General Lyles asked if cyber standards were automatically embodied in standards development. Mr. Gerstenmaier explained that NASA can pass European Space Agency (ESA) data through all its networks and vice versa; the data can be source-encrypted, and is pipeline-independent. He noted that he would ask his teams to consider more rigor. Lieutenant General Lee Levy, a newly appointed NAC member, commented that at DoD, cybersecurity standards had more to do with software standards; DoD has had to buy systems that have IP rights. He felt that cyber should be "baked in" along the way. Mr. Gerstenmaier noted that the devil is in the details, in not only controlling interoperability but also in the design aspect to avoid IP issues, and offered to show the NAC details of HEOMD's cyber standards. Mr. Gold said he hoped to have robust industry representation in his new Regulatory and Policy Committee in order to aid HEOMD in this area.

Mr. Gerstenmaier detailed ways in which NASA's open architecture principles can help to develop space, such as the development of the H-II Transfer Vehicle by the Japanese space agency, JAXA. ISS allowed extensive experimentation with interoperability in its work with both Russia and ESA; this work has, in turn, enabled NASA to segue more easily to commercial participation. The open architecture will feed into the Deep Space Gateway, operations on the lunar surface, and ultimately, long-duration cruise to Mars. Approaches in LEO do not translate directly to lunar operations, however, and there are many factors that will influence the human rating requirement. Dr. Alan Epstein, NAC ex officio member, commented that HEOMD should continue to invest heavily in propulsion. There are also the human factors in space to consider: radiation, the psychological effects of isolation and confinement, and the daunting exploratory distances from Earth.

HEOMD is actively evolving life support systems (LSS), and is kicking off next-generation LSS on ISS, with an aim to increase system reliability. ISS has also taught NASA more about failure rates, and what it will take to bring humans home safely. There is not yet a human-rated heat shield, or sufficient understanding of EDL and ascent systems, to get humans on Mars. The Commercial Crew Program, for example Boeing's Starliner project, is making progress in this area. NASA is also studying whether industry is ready to land small masses on the Moon. SLS and Orion are also making progress; engine testing is ongoing at NASA Stennis Space Center, where experimentation with 3D printed engines has reduced manufacturing time by almost a third. HEOMD is ready to go out with a PPE procurement, and to have it on contract next year. The Deep Space Gateway can be conceived of as a reusable Apollo command and service module, with reusability of the ascent vehicles, and the ability to be moved to other orbits for science purposes. This a key piece of infrastructure that will keep NASA on the cutting edge. Mr. Bridenstine commented that he wished to "double down" on Mr. Gerstenmaier's description of the Gateway as a key piece of enabling sustainability at the Moon.

Human Exploration and Operations Committee Report

Mr. Kenneth Bowersox, Chair of the NAC Human Exploration and Operations (HEO) Committee, briefed the NAC on the most recent HEO Committee deliberations. Mr. Gerald Smith has stepped down, and Mr. Mark McDaniel has joined, the committee. Their latest meeting featured a very full agenda, wherein members heard a status of HEOMD re: communications and launch support. The NAC HEO Committee also met jointly with the NAC Science Committee, and found it to be a very valuable undertaking, with much cross-pollination and parallel thinking. The NASA Exploration program is marking 18 years in space; there are three Americans and two Russians on the latest increments at ISS. Five vehicles have visited ISS in the interval between the last two HEO Committee meetings: two Russian, one Japanese, and three commercial U.S. vehicles. These vehicles have brought cargo meant for updating payloads, and delivering samples back to Earth. There are new efforts in dealing with ISS trash, using a 3D-printer to make components recyclable. An investigation is under way on whether cancer drugs can be evaluated in culture on ISS; these endothelial cell cultures grown in microgravity may replace animal models for testing drugs. ISS remains on the path to study risk reduction to humans in space; there is still work to be done even past a 2024 ISS

decommissioning. The HEO Committee also heard about an ISS "cotton sustainability challenge," a project aiming to grow cotton with less water. Mr. Gold asked Mr. Bowersox for his thoughts on the Center for the Advancement of Science in Space (CASIS), the managing arm of ISS research. Mr. Bowersox commented that CASIS has a hard job, but that they are doing better and better. He cautioned that ISS still has a long way to go before it has full commercial capability. An ISS Transition Report has been sent to Congress, and proposals are out to industry; responders include Boeing and Blue Origin, among other major players. The Transition Report also addresses NASA's long-term needs for LEO services. The HEO Committee heard briefings on the progress being made on SLS and Orion, indicating the physical manifestations: engines, tanks, and ground systems, and heard briefings on Exploration Missions (EM)-1 and 2; EM-2 will be crewed, and will perform a lunar fly-by. Dr. Patricia Sanders, Chair of the NASA Aerospace Safety Advisory Panel (ASAP), commented that HEOMD has done a good job of designing missions without introducing more risk. Regarding the latest HEO Committee summary received from the Commercial Crew Program (CCP), she conceded that more work needs to be done, to determine the postures of technical authorities, but that CCP is providing not just paper, but data and decisions. Mr. Bowersox reported that crew assignments for early EM missions have been made. Mr. Wayne Hale, NAC member, asked whether the risk issues on crew had been adequately debated, noting that once a human rating is accepted, crew size is further driven by other factors. He commented that there had been some disagreement on whether a three-person crew (vs. one-person) constituted an additional risk. Mr. Bowersox noted Mr. Hale's view.

Mr. Bowersox added that the three candidate prototypes for crew vehicles look good. He speculated whether there would be an opportunity to fly members of Congress and teachers as NASA did with the Shuttle program. He added that his favorite part of SPD-1 was the stipulation that NASA is going to Mars and beyond. Mr. Bowersox added a reminder that ISS is the template for the Deep Space Gateway (DSG) lunar orbit and surface operations. He reported that there is already feedback from international partners on DSG. PPE is being procured through a commercial approach, with a BAA to be released in September, and a contract due to be signed by March 2019. Habitation development partnerships will move forward similarly; prototypes are due next year. CLPS has an open competition under way (slide). Mars 2020, radiation monitor on MSL has shown Mars/ISS dosages are similar. MOXIE ISRU instrument to be on Mars 2020. There is a new HEOMD Deputy Associate Administrator (DAA) position for Exploration, now filled by Mr. Steve Clarke, which will help focus science efforts, and enable transformative science from lunar orbit and surface operations. A recent Deep Space Gateway workshop yielded numerous concepts, as well as engineering requirements, that will feed into other procurement plans.

The HEO Committee observed that it was important to have clear principles for ISS transition, and was encouraged to see the amount of support for the Deep Space Gateway emanating from all branches of the government. The Committee was eager to see surface plans, and expressed its support for the Gateway platform.

The HEO Committee is concerned that the SLS/Orion program might slow progress in other NASA areas. Mr. Bowersox said his personal feeling was that staying the course makes sense. The HEO Committee is also concerned about the U.S. presence on ISS until it can get Commercial Crew flying. Mr. Hale commented that he had been skeptical, initially, of the Gateway concept, but having heard the discussion several times, he had come to view the Deep Space Gateway as an appropriate way to return to, and to pursue sustainability at, the Moon for both science and human exploration. He found the orbital mechanics discussion compelling. Dr. Epstein commented that HEOMD has been jerked around for decades by policies and politics, and thought had done an excellent job of providing a plan, and the hardware that goes along with the plan. The Deep Space Gateway is useful for any human mission imaginable, and is basically a very sound way of investing U.S. resources in human exploration. General Lyles asked Mr. Bowersox to provide a summary of observations and concerns for the Administrator.

Mr. Bowersox presented a joint finding from the HEO Committee and Science Committee to the Council. Dr. Wadhwa noted that potential trades between surface and orbit operations need to be evaluated more closely. After deliberation, the Council approved the following finding to the Administrator:

> *The Council finds that the HEO Committee and the Science Committee met jointly on August 29, 2018, to review plans for the development of the cislunar Gateway, some results from previous lunar missions, and potential future exploration and science operations in cislunar space and on the lunar surface. These two NAC committees were impressed with the lvel of collaboration between SMD and HEOMD as well as the potential for future joint efforts. It was clear from the presentations at the joint session that there are many opportunities for valuable exploration and science activity in cislunar space aboard the Gateway. It was*

also evident that there is great synergy between investigations that can be performed from lunar orbit and science activity on the lunar surface. These two NAC committees look forward to a future joint session as plans mature for exploration and science activity in lunar orbite and on the surface.

Mr. Bowersox presented a second joint finding from the HEO Committee and Science Committee to the Council. After deliberation, the Council approved the following finding to the Administrator:

The Council acknowledges and applaud the direction NASA has taken toward a complementary approach to exploration that facilitates a balance between exploration and scientific discovery. The approach includes work in LEO, cislunar space (currently envisioned as the Gateway), lunar surface exploration, and deep space exploration. NASA's plans have the potential to support both HEOMD and SMD objectives and goals, while meeting the intent of Space Policy Directive-1 (SPD-1) for a return to the Moon. This concept features a role for international and commercial partners, reusability, sustainability, reconfigurable components, and builds toward the ultimate national vision for deep space exploration and science, including a crewed mission to Mars.

Mr. Bowersox presented a third joint finding from the HEO Committee and Science Committee to the Council. After deliberation, the Council approved the following finding to the Administrator:

The Council applauds NASA's inclusion of international partners in the Gateway program. The value of international cooperation goes beyond the technical synergies realized through collaborations among traditional and emerging international partners. Perhaps more importantly, space exploration, pursued as an international community, facilitates peaceful interactions at large among all participating nations.

Mr. Bowersox presented a fourth joint finding from the HEO Committee and Science Committee to the Council. After deliberation, the Council approved the following finding to the Administrator:

The HEO Committee and the Science Committees observe that new technologies being developed for terrestrial industries may be applied to both HEOMD and SMD missions, like the Gateway. For example, autonomous vehicles on Earth and space may share similar instrumentation and sensing computational capability. Developing high resolution solid state LIDAR, teleoperations, and new techniques for sensor fusion will be important for any autonomous vehicle on earth or in deep space.

General Lyles asked that this finding be held as an observation, and not be sent forward to NASA at this time. Mr. Oschmann noted that the finding was very complementary to the view of the NAC Technology, Innovation and Engineering (TI&E) Committee as well.

Mr. Bowersox presented a recommendation from the HEO Committee and Science Committee to the Council. After deliberation, the Council approved the following recommendation to the Administrator:

The Council recommends:

- *For the NASA SMD Associate Administrator: That the science initiatives implemented at the Gateway should be prioritized to align with the National Academies' decadal surveys.*
- *For the NASA HEOMD Associate Administrator: That the objectives for exploration initiatives enabled by the Gateway approach should be clearly articulated by HEOMD to set expectations for all stakeholders.*

Dr. Wadhwa commented that the prioritization of science in the joint approach is important, and should be developed alongside Decadal Survey recommendations. Mr. Bowersox noted that there is a lot of interest in work at the Gateway, and it is important to set expectations early for the interested communities to understand the constraints. Dr. Zurbuchen stated his view that the recommendation was well thought out.

STEM Education Task Force Report

Dr. Aimee Kennedy, Chair of the NAC STEM Education Task Force, resurfaced a perennial recommendation to elevate the Task Force to Committee status. She reviewed the current membership, noting there were four new members on board. Progress continues on the NASA Office of Education's implementation of the Business Services Assessment (BSA), with many accomplishments in completing Task Force recommendations. Dr. Kennedy offered kudos to Mr. Michael Kincaid, AA for NASA's Office of Education, and his office. In the process of reframing the NASA Office of Education to become the new Office of STEM Engagement, there are three focus areas. The Task Force felt that the focus on students in the new Office of STEM Engagement has become even stronger. This is seen as a real shift. NASA is using evidence-based strategies for pre-kindergarten students all the way through to graduate school, to really amplify NASA's STEM engagement portfolio. The Task Force was excited to see this shift. New members have expressed their surprise that these programs have both continued and improved throughout the change and upheaval in recent years. Dr. Kennedy noted that there were two new things to highlight: the Year of Education on Station (YES) has seen its downlinks increase dramatically (four-fold); and Christa's Lost Lessons from Challenger video, which has received much positive attention and air time, is helping to build new resources for teachers. NASA will also be contributing to national efforts through the Space STEM Forum event at Headquarters that will take place on September 19, 2018; at that time the Office of STEM Engagement will curate the results on a single web page. The Federal STEM Education 5-Year Strategic Plan is also in draft preparation. Dr. Kennedy indicated that Administrator Bridenstine is a co-chair of the Co-STEM interagency group, thus NASA has presence in key positions in major STEM activities. The NASA Glenn Research Center has been leading the Office's evaluation and performance efforts, and is working on finalizing performance measures.

Dr. Kennedy ended her briefing with a renewed recommendation to elevate the Task Force to Committee status within the NAC. Following deliberation, the Council approved the following recommendation to the Administrator.

> *The Council recommends that the NASA Advisory Council (NAC) Ad Hoc Task Force on STEM Education should become a regular committee of the NAC.*

General Lyles asked Dr. Kennedy to put in writing her positive comments about the Office of STEM Engagement, to which she agreed.

Council Discussion

Mr. Kincaid provided some additional background on the NASA Business Services Assessment (BSA) effort. Mr. Borghese applauded NASA outreach and STEM engagement as a very important part of what NASA does, and Mr. Hale reinforced the thought. Mr. O'Brien, speaking as former Chair of the former NAC Education and Public Outreach Committee, observed that both STEM engagement and public outreach are ingrained in NASA. Dr. Penina Axelrad asked if the Task Force had Space Grant involvement, and suggested the Task Force might add more representation for more balance in this area. Mr. Oschmann absolutely supported the elevation of the STEM Education Task Force to full committee status, not just as an altruistic gesture, but because STEM engagement is more important than ever for supporting the future workforce. Mr. Gold thought that optics for the Education endeavor were important, remarking that there is a giant STEM gap in the U.S. Midwest that is being filled by YES downlinks. Mr. Borghese recommended the STEM Task Force bring on heavyweights from the academic world when considering how to reach students. Mr. Tony Cole suggested the Task Force consult some young companies that are focused on the STEM market, such as Code to the Future. General Lyles stated that he expected that Administrator Bridenstine would agree with the elevation of the Task Force to full NAC committee status, and that additionally an outreach committee might be formed

August 30, 2018

Call to Order, Announcements

General Lyles called the meeting to order, and Ms. Rausch made brief administrative announcements.

Opening Remarks by NAC Chair

General Lyles introduced the day's agenda, and asked Council members to consider how changes in the NAC current structure might better serve the NASA Administrator. He welcomed future input on this topic

NASA Aeronautics Research Mission Directorate Overview

Dr. Jaiwon Shin, Associate Administrator of the Aeronautics Research Mission Directorate (ARMD), presented an overview of the NASA Aeronautics program. This year, NASA began a $250M contract with Lockheed Martin to design and build the Supersonic Technology Demonstrator (X-59), and is very excited to re-enter a new X-plane era after many decades of hibernation. Dr. Shin described the process of developing the NASA Strategic Implementation Plan that has included many interactions with industrial partners to figure out what is needed for the U.S. aviation industry for many years to come. NASA performed a lot of global landscape analysis, considering sociological, geophysical, and cultural aspects, as well as economic ones, in formulating the Plan. The Plan's six strategic thrusts comprise the major focus of ARMD. The Plan received much positive feedback from industry on its clarity of vision and strategy. The thrust areas are more relevant today than they were five years ago.

Where is ARMD today? Dr. Shin emphasized the clarity aspect, which helps not only the external community, but also the internal community at the four NASA research centers (NASA Langley Research Center, NASA Ames Research Center, NASA Glenn Research Center and NASA Armstrong Flight Research Center), particularly with respect to workforce planning to support the ARMD mission. Each center has unique capabilities for Aeronautics. NASA Ames especially strong in the areas of air traffic management and safety. ARMD has successfully avoided duplication and competition and has fostered a collaborative atmosphere between the four NASA research centers, with a dedicated and committed workforce, by far the greatest asset. ARMD has spent a lot of time and energy in pursuing partnerships with key agencies and industry, and meets with its counterparts on a regular basis to ensure programs are working well. Through the forging of robust relationships, the Aeronautics industry now understands the role of NASA ARMD in reducing risks in cost-sharing partnerships. For instance, NASA just finished a six-year project in reducing environmental impacts; out of $350M, NASA spent $250M in kind. ARMD is also working to protect IP and taxpayer dollars by working closely with industry partners from day one and working through the risk reduction process, transferring knowledge well before the results become public domain, up to two generations ahead of publication.

General Lyles asked if ARMD would benefit from a Space Policy Directive for Aeronautics. Dr. Shin felt that such a directive would certainly help. He noted that there is precedent policy set during the Bush Administration that is still in force. Back then, NASA tried, unsuccessfully, to convince the White House that there needed to be an industry policy as well as a research and development (R&D) policy for Aeronautics. The question illustrates the point, however, that global competition is growing by leaps and bounds; a policy would help to level the playing field. The U.S. must face up to the global challenge, and strengthen the relationship between government and industry in Aeronautics. NASA should concentrate on research that the industry and the country needs. General Lyles said he remained mindful of the fact that the National Space Council is also concerned with the Aeronautics sector, and that he would take up the subject with the NASA Administrator.

Dr. Shin pointed out that ARMD is not the end-user of the technology it produces, giving it a unique identity. NASA works to ensure that it executes programs through setting and following best practices; ARMD's practices have been praised widely. The global growth in aviation is staggering; it is expected that the current 4B passenger trips per year will increase to 7.8B passenger trips per year by 2036. More people in the Asia Pacific region are travelling, forecasting the need for over 40,000 new aircraft, representing a market value of $6.1 trillion. China has been investing heavily in new aircraft engines, as are Russia and Canada. The global landscape is changing, and much innovation is occurring. Boeing Corporation is purchasing 90% of the commercial side of the Brazilian entity, Embraer, and is in the final stage of closing the deal. These are very interesting dynamics, and the heat is on U.S.

competitiveness. In addition, urban air mobility is another exciting potential market. There is a tremendous demand to alleviate traffic congestion in urban areas all over the world. Technologies are coming together to turn air taxis and "flying cars" into a reality. Regulatory, safety and societal issues present barriers to this reality, but there is strong demand. Silicon Valley is investing heavily in these concepts, and the phenomenon is global. There are literally hundreds of design concepts. While there is much hype, major companies such as Boeing and Airbus are investing in the area as well. Uber also has an ambitious plan to build an urban air mobility architecture, and will begin demonstrations in Los Angeles and Dallas in 2020. NASA must ensure that there is system-wide research to bolster and match the industry effort, methodically working with the community to find enabling technologies to help the market take off. NASA must look below the 2000-3000 foot altitude: this is the airspace for urban air mobility. Today it is regulated, but it is not actively managed. In the near future, there could be thousands of flights per day. Today's air traffic management system will not work in this arena, thus there must be a new paradigm.

NASA Aeronautics has been proactively leading the effort in addressing all of these issues, particularly in the integration of urban air vehicles into the national air traffic system, as well as supersonic flight and electric aircraft. ARMD is not developing next-generation supersonics. NASA does not believe this is a government role, and the market is uncertain. NASA is re-examining, however, the role of supersonic flight over land, and ways to generate lower sonic boom. The goal is to deliver the data to the regulatory agencies, which might help overturn the complete ban. It remains to be seen if industry will jump into the market. The X-59 has a very singular purpose; it will fly over communities and measure responses. The boom may be able to be embedded in the urban soundscape. International regulatory agencies are also awaiting the results.

In the realm of electric aircraft, there is the clear need for safety, and the question of bringing hybrid-electric systems to the aircraft industry. NASA's role here is to inform, educate, and provide scientific data, and in so doing the Agency is concentrating on first-of-a-kind, seminal projects. To illustrate the importance of NASA's mission, Honeywell and United Airlines have brought in their aircraft to participate in testing, on their own dime, in research areas such as fuel consumption reduction and precision landing. From the budget perspective, ARMD has gotten much support, close to $700M in FY 2019. On Capitol Hill, both the House and Senate have increased the budget in the markup period, for the first time ever. ARMD continues to lay the groundwork for 2040. This is an exciting time, almost like a Wright Brothers era. The excitement provides great motivation for the workforce, as well. Mr. Gold asked if NASA had had any interaction with Virgin Atlantic's "citizens in space" planning. Dr. Shin said that in ARMD's hypersonic research in portfolio, there is some interaction with Virgin Atlantic; NASA is mindful of the possibilities. Dr. Elisabeth Paté-Cornell asked if ARMD was studying the tilt-rotor concept. Dr. Shin replied that tilt-rotor vehicles were still in play, but that the industry was looking at much smaller vehicles (2-3 passengers), using small multiple (quiet) rotors. It is not known what will prevail in the urban air market. Asked how cooperation with the Air Force and DoD was faring, Dr. Shin described NASA's good relationship, marked by steady interactions, with the Air Force in the areas of hypersonics, mobility, and autonomy research, as well as with the Air Force Research Laboratory (AFRL). There is a NASA/AFRL executive research committee. NASA is greatly interested in being more involved with these joint efforts. General Lyles complimented Dr. Shin on his continuing fine work.

Aeronautics Committee Report

Mr. John Borghese gave an update on the NAC Aeronautics Committee, which has welcomed four new members: Eric Allison (Uber); Scott Drennan (Bell); Anil Nanduri (unmanned air vehicle business for Intel); and Tom Shih (Aeronautics at Purdue). These new members are reflective of the modern direction. The Aeronautics industry is beginning to see very large companies moving into new markets. The Aeronautics Committee heard numerous briefings on Urban Air Mobility (UAM), Unmanned Air Craft System Traffic Management (UTM) and the LBFD, and saw a lot of interaction between the Aeronautics Committee and NASA on these topics, and much detailed discussion. There are about 10M flights per year today, globally, and projections indicate there will be a roughly two-order-of-magnitude expansion, which will require a greatly expanded concept of air space management, as well as advanced technology and methods for electric vehicle development. The grand challenge is how we will put new vehicles and new air space together. NASA has contracted two UAM market studies to study vehicle development and production, vehicle maintenance, air space design and implementation, air traffic management systems, and community integration (i.e. new vehicles flying in urban environments). By 2028, an air metro environment could be profitable and result in 750M flights annually. Such a volume will require a completely different air traffic system, and safety will be paramount.

NASA has initiated an Urban Air Mobility Grand Challenge, in which the Agency will be asking industry to bring their own vehicles to test the overall integration of an air traffic management system. NASA will provide the testbed and models with the goal of developing common safety and integration scenarios. The last step of the Grand Challenge will be community integration, fleshing out the unknown unknowns, and building public confidence. Mr. Borghese noted that NASA's Aeronautics work, to date, has shown the value of the collaborative effort to technology transition. Mr. O'Brien asked if anyone was looking at the impact of noise pollution, as even small drones are noisy. Mr. Borghese said that yes, this is under active consideration, adding that electric air vehicles tend to be less noisy. However, the Grand Challenge is addressing noise. Dr. Epstein commented that in some locales, noise may always be unacceptable; Uber Elevate has looked at the problem and has some suggested metrics, and creating corridors for approach to landing sites. Historically, NASA has great expertise in noise reduction research: the question is how quiet does it have to be, and how do you get it quiet enough? NASA should test urban noise in the same way it is testing the X-59; the answer will be different in different locales. Noise is a non-trivial point; it will affect the feasibility of a growing market. Mr. Cole addressed the question of safety, and whether all aspects are being studied in the Grand Challenge. Can hackers take control of these vehicles? Mr. Borghese commented that at current safety rates, one would expect 150 accidents per year. What will be the bar that describes safety from anything from cyber intrusion to electromechanical failures? The safety question can completely eradicate the possibility of urban air mobility.

Following deliberation, the Council approved the following Aeronautics Committee finding for the ARMD Associate Administrator:

> *The Aeronautics Committee finds that the Urban Air Mobility (UAM) Grand Challenge is a great initiative for NASA to set the leadership beacon on UAM that inspires the industry and the next generation of workforce alike. While it is in the early stage of planning, the Aeronautics Committee believes that the UAM Grand Challenge needs to be articulated more clearly. The Committee also observes that NASA's role is to study, estimate, and articulate the trade space for UAM. The Committee urges the project to work closely with universities to take advantage of the talent available. The Committee complimented NASA for the evolution of the relationship with the Federal Aviation Administration (FAA) and how this change has improved the level of collaboration.*

Mr. Borghese noted that NASA's UTM work is already moving into the FAA, which has regained the lead in developing these air traffic systems. NASA's impact has been noticeable. The FAA now deploys a system to automatically approve unmanned air vehicles (UAVs); this system did not exist before NASA's UTM work.

Mr. Borghese prefaced an Aeronautics Committee finding on the LBFD by providing a brief history of issues in commercial supersonic flight, which was banned in 1973. Today, aircraft engines are much more efficient than they used to be, and three major companies are working on supersonic aircraft. Simulations have shown that boom noise and sound pressure levels can be overcome. Lockheed Martin is going forward on schedule to build NASA's LBFD, with flight tests scheduled for 2022.

Following deliberation, the Council approved the following Aeronautics Committee recommendation for the ARMD Associate Administrator:

> *The Aeronautics Committee endorses the Low Boom Flight Demonstrator project and congratulates NASA for developing clear project objectives and an adequate yet aggressive schedule. The Committee observed that the risk mitigation strategy has been well-developed and the goals of the project are clearly articulated. The Committee believes that the demonstrator will reinvigorate the public view of the role of Aeronautics within NASA and encourages the project to involve schools to take advantage of this opportunity to inspire the next generation.*

Public Input

No public comments were offered during this period.

Science Committee Report

Dr. Meenakshi Wadhwa, Interim Chair for the NAC Science Committee, delivered her report. She briefly reviewed the membership and welcomed new committee members, Dr. Vinton Cerf and Dr. Mark Weiser. SMD has a large and diverse portfolio, which includes the Joint Agency Satellite System (JASS), and the four discipline divisions, Planetary, Earth Science, Astrophysics and Heliophysics. Much research and analysis (R&A) is carried out alongside SMD missions. SMD funds 10,000 scientists through 300 competitively selected awards each year. Small satellites and "cubesats" are becoming increasingly important to the science endeavor at NASA. Science highlights of note include the recent successful launch of the Parker Solar Probe (PSP), which will study the Sun, the physics of stars, solar activity, space weather, and the habitability of exoplanets. PSP marks the first time a spacecraft has been named for a living individual, Dr. Eugene Parker, a renowned heliophysicist. The Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission was launched in May 2018. The mission is comprised of twin satellites and will use interferometry to measure small perturbations in changes in mass on Earth. GRACE-FO will provide new data on ice and "brown water," the latter of which is characterized by silt, or pollutants. NASA has introduced a popular app, Another Day on Aerosol Earth, which is a global visualization of aerosols (dust, salt, carbon, etc.) in the planet's atmosphere. SMD's Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) mission is on its way to asteroid Bennu, a carbon-rich asteroid, to carry out a sample return mission, yielding up to two kilograms of material. The sample is scheduled to return to Earth in 2023. The Lunar Reconnaissance Orbiter (LRO) has provided data on the presence of fresh craters on the Moon, formed within the last billion years, which is helping to reassess the impact flux on Moon. The impact flux is higher than previously understood and can affect planning for future lunar missions. The discovery of the first interstellar object in October 2017 was the result of a PanSTARRS telescopic observation. The object has no cometary tail, but there are suggestions it might be an extinct comet, given the trajectory of the object, and the fact that it is not in the gravitational pull of the Sun, nor in the plane of the ecliptic. The Transiting Exoplanet Sky Survey (TESS), launched earlier this year as a follow-up to the Kepler mission, is optimized to detect planets around dim, red stars (M dwarves, 90% of the stars in our galaxy). TESS will detect extrasolar planets, and inform future missions that will look at the composition of exoplanet atmospheres for signs of biotic activity.

Dr. Wadhwa provided a programmatic status of SMD, which includes the addition of new staff. Dr. Michael New has stepped into the role of Deputy Associate Administrator for SMD Research. The Planetary Science Division (PSD) Director position is now open with the departure of Dr. James Green, who has been appointed NASA Chief Scientist. Dr. Michael Freilich is stepping down in the near future after 12 years as Director of the Earth Science Division. Dr. Zurbuchen added that there are plans under way to hire a new Heliophysics Division Director, and there have also some strategic changes, filling gaps relating to the James Webb Space Telescope (JWST) delay. One of NASA's top managers, Mr. Greg Robinson, now heads the JWST program. General Lyles commented that he appreciated Dr. Zurbuchen's commitment to diversity as he fills key roles.

Dr. Wadhwa noted that the Mars 2020 rover, which is essentially the Mars Curiosity rover with a different instrument suite, is on track for launch in summer 2020. Regarding JWST, NASA formed an independent review board (IRB), which subsequently made recommendations to delay the launch to March 2021, citing human errors, inexperience with new technologies, and the complexity of the mission as root causes. Dr. Zurbuchen interjected that SMD takes the JWST delay very seriously, as it is a matter of taxpayer money; NASA wants to learn from its mistakes. He related that SMD is actively addressing JWST and is reaching out to contractors, talking about the cultural issues, and meeting with all managers across NASA to discuss lessons learned. Mr. Gold noted the importance of building in serviceability for space assets like JWST. Dr. Zurbuchen pointed out that JWST is a very low-temperature structure, which creates some inherent barriers to service. However, JWST does have stickers, and grapples to enable deployment of some robotic servicing. Mr. Borghese commented that it seemed many JWST problems resulted from programmatic oversight, i.e. blocking and tackling. Dr. Zurbuchen said that NASA has implemented all IRB recommendations with respect to management. He commented that one must also keep in mind that the simplest problem is amplified manifold in a mission that is as complex as JWST. Mr. Bowersox commented that it is important to remember that the test process worked, demonstrating why diligent testing is necessary. Dr. Wadhwa noted that the bottom line is that NASA is doing extremely difficult things. Dr. Zurbuchen emphasized that everyone is openly and constructively discussing the issues.

Dr. Wadhwa discussed advancing national science and exploration goals, and how to prioritize science in the context of Human Exploration. General Lyles asked why there was not also a goal of stimulating the next generation

of scientists. Dr. Wadhwa replied that much is already folded into SMD, and that stimulating the next generation is an idea that is embedded throughout all science mission activities. Dr. Zurbuchen said there were three ways in which SMD engages the public: telling the science story and sharing news; having students build instruments; and using a dedicated pool of money for outreach. He noted that in the past, every NASA mission required a commitment to Education and Outreach; this arrangement has transitioned to a separate pool of funds. Dr. Zurbuchen hoped to get back to being as deeply engaged in Education as SMD had been in the past. Mr. O'Brien said he had once argued that Outreach and Education should be a mission requirement. Dr. Zurbuchen indicated that the NAC Science Committee has been engaged in many discussions to bring this requirement back. Asked about the lunar project, Resource Prospector, Dr. Zurbuchen said that NASA was going forward to transition RP to science, to provide mobility on the surface of the Moon. Dr. Wadhwa reported on a new initiative, the Apollo Next Generation Sample Analysis (ANGSA) program, for which research awards are expected by early 2019. ANGSA will re-examine Apollo samples with the newest analytical tools. The Science Committee addressed the role of public/private partnerships and identified some focus areas, such as artificial intelligence, citizen science, and environmental sensing projects (urban heat islands) in cooperation with the Department of Energy and the private sector. The Science Committee also wrapped up two major tasks on an SMD R&A charge and the subject of Big Data; the NAC Big Data Task Force has been decommissioned. Mr. Gold asked if NASA had reached out to DoD on subject of artificial intelligence. Dr. Zurbuchen said he was aware of the DoD activities and made a note to follow up on them.

Following deliberation, the Council approved the following finding for the SMD Associate Administrator:

> *The Science Committee finds that SMD should "stay the course" with the overall Research and Analysis (R&A) strategic objectives, incorporating attention to high-impact/high-risk research, as history has shown that such investment can be game-changing. Just because incremental progress is being made, it does not mean that tremendous impact is not occurring. In general, key to the selection of high-impact/high-risk proposals is for SMD to:*
>
> 1) *Clearly train review panels regarding high-impact/high-risk research, and encourage proposers and review panels to address and evaluate mitigation of risk in high-impact/high-risk proposals;*
> 2) *Have attendant expertise on the review panels;*
> 3) *Closely coordinate with each program manager on this approach; and*
> 4) *Have the high-impact/high-risk solicitation remain within each SMD discipline rather than in a separate proposal call that mixes disciplines, as it could not be reviewed effectively. In each solicitation, SMD could note that high-impact/high-risk proposals are welcome. This approach results in high-impact/high-risk research embedded in each review panel for their examination, which is beneficial.*
>
> *Finally, the NAC Science Committee finds that SMD effectively responds to the scientific community when an interdisciplinary research need is identified, and sets up appropriate structures to promote such collaboration. Most interdisciplinary work is being done through collaborative research mechanisms, e.g. Nexus for Exoplanet System Science (NExSS), NASA Astrobiology Institute (NAI), and may not exist outside of these. To increase emphasis:*
>
> 1) *SMD could encourage the scientific community to increase communication with the Science Committee in pinpointing interdisciplinary/interdivisional opportunities; and*
> 2) *The next SMD Research Opportunities in Space and Earth Science (ROSES) call could welcome proposals wherein astrophysics data will be used by planetary science investigators, and conversely, planetary science data will be used by astrophysics investigators.*

Following deliberation, the Council approved another finding for the SMD Associate Administrator as follows:

> *The Science Committee finds the enthusiasm of the NAC Ad Hoc Task Force on Big Data (BDTF) impressive. The BDTF completed a large amount of work and provided a very thorough report. Many of the BDTF's findings and recommendations reflected the thinking of the NAC Science Committee, with divergences often having to do with how ideas are implemented by SMD. Overall, the NAC Science Committee agrees with the BDTF that SMD data archive programs and projects are performing well and*

are properly taking steps to modernize. However, the volume, variety and velocity of NASA science data is taxing established methods and technologies. The Science Committee finds that SMD should:

1) *Make investments in hardware, software, training and education to accelerate modeling workflows;*
2) *Participate in the Department of Energy (DOE) exascale computing program;*
3) *Implement server-side analytics (SSA) capabilities (with caution);*
4) *Forge a joint program with the National Science Foundation (NSF) Big Data Innovation Regional Hubs and Spokes program; and*
5) *Incorporate data science and computing advisory positions in the SMD advisory committees*

In all efforts, the Science Committee underscores that it is important that data science and computing experts work closely and collegially with domain scientists to implement effective solutions that are based on an understanding of the domain.

As to the future, the Science Committee commends that an SMD Strategic Data Working Group has been set up that will bring forward these ideas, without interfering with how each division manages data.

On the Big Data issue, Dr. Wadhwa said the key takeaway message was that NASA archives were very valuable in producing research papers.

Space Technology Restructuring at NASA

Mr. Steve Jurczyk, NASA Associate Administrator, updated proposed plans to restructure STMD per the language of the President's Budget Request for FY 2019. To date, the Agency has not made a decision relative to the Budget Request, in which NASA has been directed to restructure the STMD budget into themes: Deep Space Exploration Systems; Exploration Research and Technology, and LEO and Space Flight Operations, the latter of which includes space communications programs. STMD content is to be restructured into Exploration Research and Technology line. The Budget Request has also directed organizational restructuring with two options, either keeping space technology as a single directorate or splitting it into two directorates. NASA has proposed a third option to the NASA Administrator, which preserves a separate space technology directorate and moves some advanced exploration focus to Space Technology, leaves HEOMD as is, and keeps the Human Research Program in HEOMD. A team has assessed the three options using three figures of merit, and considered responses to stakeholders, the complexity of interfaces, organizational efficiency, sustainability, resilience to policy change, and vulnerability to budget. There is also a desire to prevent disruption of programs that are in progress, and an effort to characterize risk mitigation strategies. The plan has received from feedback from Capitol Hill through markups; the House has made some specific recommendations on having separate account in Space Technology. The Senate had some similar comments. Ultimately, the NASA Administrator will make the final decision.

Mr. Borghese felt that the most important factor to consider was the motivation and enthusiasm of workforce, because of the risk of losing their interest. Mr. Jurczyk said this factor had been part of the figure-of-merit discussion. NASA is also looking at elements of the Gateway and how to fund it, to ensure there will be an acquisition and procurement strategy going forward during the reorganization. NASA has had the necessary discussions to flesh out the NASA Center roles; this activity is ongoing and will go on independently from another action, which is from the Office of Management and Budget (OMB) and is part of the Federal Government reorganization. This action would convert some or all of NASA centers to Federally Funded Research and Development Corporation (FFRDC) models, allowing NASA to be more flexible in responding to SPD-1. NASA will be delivering its report shortly to OMB, and it will entail a NASA study on the merits of FFRDCs. The concept has been studied over the last few decades, and it is generally agreed that it would be a challenging transition. Dr. William Ballhaus commented on an effort at ARC in the 1980s and agreed that it was challenging. The ARC effort had arisen as NASA aimed to facilitate attracting computer scientists with adequate salaries. Mr. Gold complimented the way NASA had handled PPE with the BAA approach, in both substance and procurement. Asked if NASA could employ a standing BAA approach, Mr. Jurczyk felt there were no legal or procurement impediments to such an approach, but rather more of a cultural impediment. A pathfinder approach might open the way to do more business in this manner.

Technology, Innovation and Engineering Committee Report

Mr. J.M. Oschmann, subbing for Committee Chair William Bauhaus, reported on the latest meeting of the NAC Technology, Innovation and Engineering (TI&E) Committee, beginning with a reminder of the Committee's scope, looking at technology across NASA, and beyond the confines of STMD. He thanked Dr. Tu and ARC for hosting the NAC and for providing excellent tours. STMD in 2018 included 3000 proposals with 700 selections, 300 university partnerships with 120 universities, and 60 projects leading to flight demonstrations. There are at present 1000 active technology projects. Since 2011, over 850 STMD activities have been transitioned to SMD, HEOMD, or a commercial entity. The participation has included historically black colleges and universities (HBCUs) and other minority institutions. Mr. Gold commented that it was particularly important to seek more diversity of people, which has been repeatedly shown to lead to diversity of ideas. Mr. Oschmann noted that commercial industries have grown in diversity as well, and NASA should leverage this effort. The TI&E Committee received a briefing on autonomous systems from Dr. Terry Fong, who indicated that there are many projects ongoing with other agencies, commercial areas, and in science. NASA can use autonomy Agency-wide, including in ground systems, aerospace management, and human space systems. Dr. Fong reports to STMD, but his function is across the Agency. His briefing included a report on Astrobee, a free-flying robot for ISS EVAs. Astrobee is envisioned as future caretaking application for unmanned periods at Gateway. A distributed spacecraft autonomy project is completing formulation to start potentially in FY 2019. The Integrated System for Autonomous and Adaptive Caretaking is being designed to offload routine work from astronauts, and monitor and maintain systems during uncrewed periods. The Solar Electric Propulsion (SEP) project, managed by Glenn Research Center and funded by STMD, and also part of PPE under HEOMD, is one of the mechanisms for moving Gateway. SEP has made good progress on the ground and in the lab, and an advanced PPE contract has been awarded to Aerojet/Rocketdyne. NASA Glenn Research Center and the Jet Propulsion Laboratory are sharing a project to reduce Hall Thruster risks. The plan is to have SEP manifested on the first PPE mission. NASA will complete the qualification testing, then move the unit on to the prime contractor.

The TI&E Committee received a briefing from the Office of the Chief Technologist (OCT), who reported that NASA has formed a Science and Technology partnership forum with the Defense Advanced Research Projects Agency (DARPA), the Air Force Research Laboratory, NOAA, the Naval Research Laboratory, and with industry. The forum meets regularly and addresses four topic areas: small satellite technology, Big Data analytics, in-space assembly, and cybersecurity. The forum has produced a white paper on in-space assembly that touches on elements of Gateway, lunar surface operations, and in-space assembly of large telescopes. General Lyles noted that DOE and the National Science Foundation were not represented at the forum, and that broader representation was needed in the partnership.

Current OCT studies include the subject of technology infusion over the business "valley of death." In the realm of In-Space Robotic Manufacturing and Assembly, three contracts have made good progress: Dragonfly, CIRAS, and Archinaut. Phase II procurement underway. Mr. Gold commented on the broader applicability of in-space assembly: the great hope is to be able to manufacture satellites on orbit with "IKEA components" at the ISS, and 3D-printing manufacture of component parts. This capability would be good for both NASA and industry. Mr. Borghese asked if it were possible to develop a robot assembler with some level of intelligence. Mr. Oschmann noted that there are some efforts in coated structures and embedded sensors that fold together artificial intelligence and autonomy. In addition, NASA does have some projects with universities that are starting to address the concept.

The CUBES project is a multiple university consortium on bio-manufacturing for deep space exploration; its divisions are microbial media and feedstock divisions; biofuel and biomaterial manufacturing to produce propellants; food and pharmaceutical synthesis; and systems design and integration. One project applies specific light spectra to induce the more efficient growth of lettuce. Other projects that support the vital role of space technology in exploration are 3D woven compression pads, composite joints, sensors, precision landing sensor, SEP, optical communications (laser communications for more distant missions), reentry materials, long-term cryogenic storage at Gateway and on the lunar surface. The TI&E Committee believes that much good progress has been made in these areas. Mr. Bowersox commented that attacking problems from a systems engineering viewpoint, i.e., adding chemical engineers and biologists to the Exploration program, is very important.

New STMD Tipping Point partnerships include 10 proposals from 6 companies, all of which have benefits for GEO and LEO, the launch vehicle industry, and the return to the Moon and beyond.

Mr. Oschmann presented a reiteration of the TI&E Committee's March 2018 finding, and the NASA response; he felt strongly that it is important to have a combination of mission pull, and at the same time, to retain the "seed corn" of new ideas. Just as an example, advances in cryotechnology have benefited JWST and will benefit missions that want to go even colder. General Lyles said he liked the seed corn descriptor, and would reinforce the finding with the NASA Administrator. Mr. Gold commented that lessons learned from the Federal Government are important, but it is much better when the industry and the Federal Government work together. Dr. Wadhwa asked whether STMD has considered the cryogenics infrastructure that would be required for future sample analysis, such as for Mars sample return. The National Academies is calling out the issue in an emerging report. Mr. Oschmann replied that the issue is not specifically addressed at STMD, but that the main message is to keep advancing the technology, which falls into the same category addressed by the March finding. It would also be important to think about some *in-situ* sample analysis on Mars. In addition, the astrophysics community would be very excited about building large telescopes in space: how will NASA get enough momentum to stay on the path? Dr. Bauhaus indicated he had nothing to add to the discussion, noting that Mr. Jurczyk knows the issues well.

Council Discussion and Final Wrap-up

General Lyles wrapped up the discussion and planned a tentative date of December 6-7, 2018, for the next NAC meeting, to take place at either NASA Kennedy Space Center or NASA Marshall Space Flight Center. He then asked for general final comments around the table. Mr. Hale noted that a small air leak had been detected on ISS, and that there appeared to have been a micrometeoroid and orbital debris (MMOD) strike on Soyuz; the puncture was not critical, but it is the first such known penetration, and a somber milestone. Dr. Sanders commented that MMOD poses the highest risk for crew; there is not a close second. Mr. Hale also commented that by Executive Order, Federal employees would not get a pay raise this year; such moves are a barrier to the retention of good employees. He further commented that NASA now has a great model in commercial cargo resupply, and commercial crew has the potential to be cost-effective. He felt that perhaps NASA and the NAC should consider commercial providers for human-rated lunar landers. Finally, Mr. Hale expressed his continuing concern about safety and risk decisions about commercial crew, commenting that it is always a balance and a risky business. The Council will need to support leadership in making these decisions. Dr. Sanders agreed, adding that risk is a conscious assumption, after having looked at the alternatives. Dr. Ballhaus, referencing the JWST IRB review, noted that it is known that humans will make mistakes, thus NASA must have mechanisms in place to catch and correct errors. Dr. Paté-Cornell commented that it is not possible to entirely retire risk, and that perhaps NASA should change the way it phrases the concept. The regulation of safety in unmanned vehicles must be based on experience and technology. NASA must also undertake a comprehensive review of cyber risk and cybersecurity, particularly for autonomous systems. Dr. Lyles commented that the NASA Aerospace Safety Advisory Panel (ASAP) is doing a deep-dive into cybersecurity issues, and can update the Council on its findings at the next meeting. Mr. Gold requested a briefing on lunar lander progress, as it would be good for the NAC to weigh in before a course is finalized at NASA. He also asked for a more detailed briefing on the details of the STMD re-organization, and wondered whether NASA should extend its ongoing studies in commercial ventures in LEO, to the lunar space, to understand how real the possibilities are. General Lyles suggested attendance at a HEO Committee meeting to see more detail. Mr. Gold thanked General Lyles and the NAC Staff for an excellent meeting.

Lt. General Levy expressed his appreciation to the NAC and ARC support teams, and commented on risk and decision-making: there is the technical risk assessment, but there must be a well thought-out communication of the discussion both internally to NASA and to the public. General Lyles felt there might be a need to stand up a separate committee to address risk. Dr. Sanders also expressed concern about how risk messaging is portrayed, pointing out that things can and do go wrong. ISS works problems every day, and while NASA makes the process seem easy, it is most definitely not. Mr. Cole commented that cybersecurity is really about risk mitigation, and wanted to have a better look at NASA's cyber programs without actually disrupting the programs. Mr. O'Brien said that making hard stuff look easy is not good, and that NASA needs to talk about the real risk without being fear-mongers. He added that he had enjoyed the meeting, appreciated the NASA Administrator's enthusiasm, and finally, that it was important to have a standing committee on STEM and Outreach. Mr. Oschmann said he had been honored and enthused to be at the NAC meeting. Dr. Wadhwa appreciated the opportunity to interact with the NAC and to hear directly from the NASA Administrator; it was also beneficial to have Dr. Zurbuchen participate more closely and provide answers to some questions. Mr. Borghese felt that it had been the best meeting yet, from the NASA Administrator's clear direction, to the meeting logistics. He echoed the previous comments on risk, particularly with

regard to UAVs, where headline news had the potential to set the effort back. Mr. Bowersox concluded with kudos for a great meeting. General Lyles expressed his appreciation for the NAC and NASA Ames Research Center support staff.

General Lyles adjourned the Council meeting at 4:07 pm.

APPENDIX A

AGENDA

NASA ADVISORY COUNCIL

NASA Ames Research Center
NASA Ames Conference Center
Building 3, Ballroom
Moffett Field, CA 94035

August 29-30, 2018

PUBLIC MEETING

Wednesday, August 29, 2018

1:00 pm	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
1:05 pm	Opening Remarks by NAC Chair	General Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council
1:15 pm	Welcome to NASA Ames Research Center	Dr. Eugene Tu Director, NASA Ames Research Center
1:30 pm	Remarks by NASA Administrator	Mr. James Bridenstine NASA Administrator
2:30 pm	NASA Exploration Update	Mr. William Gerstenmaier Associate Administrator Human Exploration and Operations Mission Directorate NASA
3:15 pm	Human Exploration and Operations Committee Report	Mr. Kenneth Bowersox, Chair
4:00 pm	STEM Education Task Force Report	Dr. Aimee Kennedy, Chair
4:30 pm	Council Discussion	All
5:00 pm	Adjourn	

Thursday, August 30, 2018

10:30 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
10:32 am	Opening Remarks by NAC Chair	General Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council
10:35 am	NASA Aeronautics Research Mission Directorate Overview	Dr. Jaiwon Shin Associate Administrator Aeronautics Research Mission Directorate NASA
11:15 am	Aeronautics Committee Report	Mr. John Borghese, Chair
12:00 noon	Lunch	
1:00 pm	Public Input	
1:05 pm	Science Committee Report	Dr. Meenakshi Wadhwa, Interim Chair
1:45 pm	Space Technology Restructuring at NASA	Mr. Steve Jurczyk Associate Administrator NASA
2:45 pm	Technology, Innovation and Engineering Committee Report	Dr. William Ballhaus, Chair Mr. James Oschmann, Member
3:30 pm	Council Discussion and Final Wrap-Up	All
4:00 pm	Adjourn	

APPENDIX B
NASA ADVISORY COUNCIL MEMBERSHIP

Position	Council Members
Chair – NASA Advisory Council	**General Lester Lyles,** *USAF (Ret.)*
Chair – Aeronautics Committee	**Mr. John Borghese,** *Rockwell Collins ATC*
Chair – Human Exploration and Operations Committee	**Mr. Kenneth Bowersox,** *U.S. Naval Aviator (Ret.); Former NASA Astronaut*
Interim Chair – Science Committee	**Dr. Meenakshi Wadhwa,** *Professor and Director, Center for Meteorite Studies, Arizona State University*
Chair – Technology, Innovation and Engineering Committee	**Dr. William F. Ballhaus, Jr.,** *President and CEO (Ret.), The Aerospace Corporation; Former Director, NASA Ames Research Center*
Chair, Regulatory and Policy Committee	**Mr. Michael Gold,** *Vice President for Regulatory and Policy, Maxar Technologies*
Member at Large	**Dr. Penina Axelrad,** *Professor and Chair, Department of Aerospace Engineering Sciences, University of Colorado, Boulder*
Member-at-Large	**Mr. N. Wayne Hale,** *NASA (Ret.), Consultant, Special Aerospace Services*
Member at Large	**Dr. Elisabeth Paté-Cornell,** *Professor and Founding Chair, Department of Management Science and Engineering, Stanford University*
Member at Large	**William B. (Tony) Cole,** *FireEye and Global Government CTO*
Member at Large	**Mr. Miles O'Brien,** *Independent Journalist*
Member at Large	**Lt. General Lee Levy,** *U.S. Air Force*
Ex Officio Members	**Dr. Alan H. Epstein**, *Chair, Aeronautics and Space Engineering Board, National Academy of Engineering* **Dr. Fiona A. Harrison,** *Chair, Space Studies Board, National Academy of Sciences*

APPENDIX C

MEETING ATTENDEES

NASA Advisory Council Members:	
General Lester L. Lyles, *Chair*	U.S. Air Force (Ret.)
Dr. Penina Axelrad	University of Colorado, Boulder
Mr. Kenneth Bowersox	U.S. Navy (Ret.)
Mr. J.M. Oschmann *(sub for Dr. William Ballhaus)*	Ball Aerospace
Mr. William (Tony) Cole	FireEye
Mr. John Borghese	Rockwell-Collins ATC
Dr. Alan H. Epstein, *Ex Officio*	Chair, Aeronautics and Space Engineering Board
Mr. Michael Gold	Maxar Technologies
Mr. N. Wayne Hale	Special Aerospace Services, Former NASA (Ret.)
Dr. Aimee Kennedy	Battelle
Lt. General Lee K. Levy	U.S. Air Force
Mr. Miles O'Brien	Independent Journalist
Dr. Elisabeth Paté-Cornell	Stanford University
Dr. Meenakshi Wadhwa	Arizona State University
Dr. Patricia Sanders	Chair, NASA Aerospace Safety Advisory Panel
Ms. P. Diane Rausch, *Executive Director*	NASA Headquarters
NASA Attendees:	
Elaine Denning	NASA Headquarters
Jamie Favors	NASA Headquarters
Beverly Girten	NASA Headquarters
William Gerstenmaier	NASA Headquarters
Mike Kincaid	NASA Headquarters
Marla King	NASA Headquarters
Bette Siegel	NASA Headquarters
Eugene Tu	NASA Ames Research Center
Thomas Zurbuchen	NASA Headquarters
Other Attendees:	
Francesco Bordi	Aerospace Corporation
Mary Floyd	Zantech IT, Inc.
Joan Zimmermann	Zantech IT, Inc.
Webex Attendees:	
Alexander Van Dyke	NASA Ames Research Center
Alfred Tadros	Space Systems Loral
Angela Clark-Williams	Electrosoft
Ariel Pink	Innovative Federal Strategies
Bill Peterson	Self
Brenda Bigelow	Self
Carl Rigg	Self
Chris Gilbert	VE Consultant
Tamara Belson	NASA Headquarters
Dan Woods	NASA Headquarters
Darrell Branscome	NASA Consultant
David Cheuvront	NASA Johnson Space Center (Ret.)
David Seidel	Jet Propulsion Laboratory
Ellen Grant	NASA
Emre Kelly	Florida Today
Erin Kennedy	Government Accountability Office

Garry Burdick	Jet Propulsion Laboratory
Gene Mikulka	Talking Space
Hemil Modi	STC
James Dean	Florida Today
James Johnson	NASA
Jeff Foust	Space News
Jeffery Hollingsworth	NASA Ames Research Center
Jose Ramos	Government Accountability Office
Kartik Sheth	NASA Headquarters
Kathryn Hamilton	NASA
Keith Cowing	NASAWatch.com
Kenneth Chang	New York Times
Lika Guhathakirta	NASA Headquarters
Loren Grush	The Verge
Marchel Halle	Self
Marcia Smith	SpacePolicyOnline.com
Margaret Roberts	NASA Headquarters
Marguerite Broadwell	NASA Headquarters
Meredith McKay	NASA Headquarters
Mike Wall	Space.com
Patrick Besha	NASA Headquarters
Rachel O'Connor	Aerospace Corporation
Robert Zimmerman	Symbio Tek
Sara Kravitz	NASA Ames Research Center
Scott Smas	Arizona State University
Stephen Clark	Space Flight Now
T. Jens Feeley	NASA Headquarters
Theodore Kronmiller	Law Office
Unmeel Mehta	NASA
Yogurt Kurkum	NASA
William Ballhaus	Aerospace Corporation (Ret.)

APPENDIX D

LIST OF PRESENTATION MATERIALS

1) Welcome to NASA Ames Research Center – Dr. Eugene Tu
2) NASA Exploration Update – Mr. William Gerstenmaier
3) Human Exploration and Operations Committee Report – Mr. Kenneth Bowersox
4) STEM Education Task Force Report – Dr. Aimee Kennedy
5) NASA Aeronautics Research Mission Directorate Overview – Dr. Jaiwon Shin
6) Aeronautics Committee Report – Mr. John Borghese
7) Science Committee Report – Dr. Meenakshi Wadhwa
8) Space Technology Restructuring at NASA – Mr. Steve Jurczyk
9) Technology, Innovation and Engineering Committee Report – Mr. J.M. Oschmann