National Aeronautics and Space Administration Washington, DC

# NASA ADVISORY COUNCIL

December 10-11, 2018

NASA Headquarters Washington, DC

# **MEETING MINUTES**

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P. Diane Rausch Executive Director

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Lester L. Lyles Chair

# NASA ADVISORY COUNCIL

## NASA Headquarters Program Review Center, Room 9H40 Washington, DC

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Meeting Report prepared by Joan M. Zimmermann, Zantech IT

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#### **PUBLIC MEETING**

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#### Call to Order, Announcements

NASA Advisory Council (NAC; or Council) Executive Director, Ms. P. Diane Rausch, brought the third and final 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, <u>www.nasa.gov/offices/nac</u>. The first two hours of the meeting were to be televised on NASA TV, primarily to broadcast opening remarks given by the NASA Administrator, Mr. James Bridenstine. 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 noted that since the NAC's previous meeting in August 2018, there had been much activity in the space community, and that it had been great for both NASA and the country. NAC has been deliberating on a wide variety of matters, from aeronautics to STEM engagement. General Lyles expressed his continued honor to be associated with the NAC, which to date has held approximately 160 meetings since its inception in 1977. The present NAC meeting was the second one held under the leadership of NASA Administrator James Bridenstine.

#### Remarks by NASA Administrator

Mr. Bridenstine thanked General Lyles and the NAC for their valuable time, and recounted the history of NASA, back to its origins as the National Advisory Committee for Aeronautics (NACA). He noted that because NASA spends much of its time with its head down, getting things accomplished, advisory groups can help NASA bring its head up to look at other matters; thus the NAC continues to serve the country in its way. The Agency will be celebrating the 50<sup>th</sup> anniversary of the Apollo 8 mission this week at the National Cathedral. Apollo 8 was the first mission to bring humans to another world as the U.S. astronauts they orbited the Moon on Christmas Eve, 1968. At that time, the Apollo Program represented a contest between two superpowers, the United States and Soviet Union, in technology, politics, and the economy, and was marked in its early days by two terrible failures. However, inspired by U.S. intelligence information that indicated that the USSR was planning to go to the Moon by the end of 1968, NASA committed, at the assumption of great risk, to reaching the Moon, and did so successfully on December 21, 1968. It is significant to note that there was no "lifeboat" (landing module) for the Apollo 8

astronauts. The astronaut crew addressed Earth on Christmas Eve, 1968, a communication that reached one out of every four people on the planet, including those behind the Iron Curtain, demonstrating space exploration as an instrument of national power. Today, the United States works on the International Space Station (ISS) with Russian partners, giving each of our governments a unique channel of communication. These partnerships have important implications for the future.

The recent landing of NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSIGHT) mission was the subject of over 200 newspaper covers worldwide, and tens of millions of social media interactions. The U.S. is still the only country that has successfully soft-landed on Mars, with InSIGHT marking NASA's eighth success. InSIGHT has international partners, which helps to change perceptions of young people in countries that are not friendly to the U.S. Space exploration, science, and discovery are every bit as important today as they were in 1968. Next year, NASA will be launching U.S. astronauts on U.S. rockets to ISS; we want to end our dependency on Russia's Soyuz rockets, but we do not want to end our partnership with Russia. Next year, commercial payload services will be going to the surface of Moon with commercial partners, under the auspices of the NASA Science Mission Directorate (SMD), opening up space with new dialogues between new partners. Mr. Bridenstine invited questions from the Council.

General Lyles said he was interested in how Mr. Bridenstine saw NASA and NAC interfacing with the National Space Council (NSpC) and its associated Users' Advisory Group (UAG). The Administrator felt it was critically important to differentiate the roles of UAG in that it gives advice to NSpC, which is comprised of U.S. Executive Branch agencies that deal with the space portfolio (State, Department of Defense, etc.). The NSpC makes recommendations to its Chair, the U.S. Vice President, who then consults with the President, who consequently issues Space Policy Directives (SPDs). SPDs are therefore interagency in nature. The NAC focuses on NASA specifically, and how it plugs into the NSpC. Mr. Wayne Hale cited the NAC's recent spirited discussion of the Deep Space Gateway, and asked Mr. Bridenstine to share his thoughts on the status of Gateway. Mr. Bridenstine pointed out that the Gateway is a direct embodiment of SPD-1, as it seeks to reach the Moon in a different, sustainable way, using and re-using every part of the architecture. It is important to reflect that the Gateway is not ISS. The Gateway is being designed to host both robotic and human-crewed landers. The glory of the Gateway is that it is a re-usable command module that can control multiple activities on the lunar surface, simultaneously. It is now known that there is water ice on the Moon, which represents water to drink, air to breathe, and the components of rocket fuel. These discoveries were made only recently; prior to this time, the U.S. had only explored equatorial regions of the Moon. Future missions will be further afield, with an open, available architecture, and with NASA's international partners. The Gateway is a tool for access to the Moon. Solar Electric Propulsion (SEP) can be used in a near-rectilinear halo orbit (NRHO) around the Lagrange points L1 and L2, allowing access to the poles of the Moon where the water ice is, and also to areas of permanent sunlight with their potential for solar charging. There are people who say we need to get to the Moon tomorrow to win the new space race; however NASA already won that race in 1969. This time, NASA needs to approach the Moon with the long game, with American leadership in action, and with international partners. NASA is not rebuilding Apollo. The Gateway is sustainable, commercial, and international in nature. The present task is to retire risk, prove safety, and ameliorate human physiology issues. The NAC has helped to support this philosophy, has considered the alternatives, and has helped pave a path to Gateway.

Mr. Bridenstine addressed NASA's recent accomplishments in aeronautics. In the coming years, the Agency is planning to prove that supersonic flight across the U.S. can be achieved without a disruptive sonic boom. This is an amazing technology demonstration that will ultimately be commercialized. NASA is also investigating all-electric power for continental flights. NASA is developing these technologies to

ensure that the U.S. stays competitive in the world market. Another important aeronautics subject is urban air mobility (UAM). NASA and the U.S. aerospace industry is investing heavily in this area. UAM is another example of "soft power" for NASA; one of the end states of such investment is that it helps the U.S. to be as strong as it can be economically. Asked about NASA's role in education and assuring the workforce of the future. Mr. Bridenstine cited the recent addition of the STEM Engagement Committee and the Regulatory and Policy Committee to the NAC. Almost everyone at NASA can tell a tale about how they were inspired by the Apollo program. The Agency does not want to be duplicative, but it does want to make sure that its stunning achievements can continue to change the direction of young people's lives; therefore NASA must stay ahead technologically, and stay ahead with its talent. NASA must inspire and engage, therefore the NAC is looking to these newly established Committees for advice. Dr. Matt Mountain commented that NASA has a role in producing unique science, and that science must be integral to what NASA does. The InSIGHT mission, for example, is a unique scientific and technological achievement. Mr. Bridenstine agreed, adding that the Gateway will host Heliophysics and Astrophysics instruments as one means of breaking down the "stovepipes" at NASA. It will also leverage activities between the Human Exploration and Operations Mission Directorate (HEOMD) and the Science Mission Directorate (SMD). As another example, the Space Launch System (SLS) will be useful for the Gateway, and also for the Europa Clipper mission, with each NASA Mission Directorate contributing to the other in cross-disciplinary capabilities.

The Regulatory and Policy Committee (RPC) has been stood up to help smooth the way for, and to leverage, commercial industry in low-Earth Orbit (LEO). Through this process, NASA can become one customer of many customers and give better value to the taxpayer. ISS is just the beginning of commercial habitation in LEO. Mr. Mike Gold, chair of the RPC, shared some initial recommendations on carrying out SPD-2, which is regulatory in nature. Mr. Gold expressed his complete faith in NASA's technical ability to execute Gateway. However, there are no technical equations for regulatory challenges, and it is important to get it right. The RPC discussed how ISS, now in a state of transition, might benefit from having its existing export control exemptions extended to commercial and free-flyers, and other ISS partners. The RPC is also recommending some changes in how NASA deals with Intellectual Property waivers, and in Committee for Space Research (COSPAR) policy, the latter with an eye to creating a balanced view of planetary protection, and potential changes in regulatory policy. The RPC also wants to change the perception that NASA discourages the use of its logo, and is recommending that NASA re-examine the value of promotional activities through the agency of its astronauts, scientists, and engineers.

Mr. Bridenstine felt it important to recognize that this is just the beginning of a policy discussion and said he was looking forward to NAC feedback on regulatory issues. If NASA can get regulatory policy right, it can more easily keep up with the speed of innovation. The ISS is the tool by which the U.S. can help to commercialize LEO. Mr. Gold and General Lyles commented that the regulatory stance was an important issue to resolve, and felt that NASA should be able to tout its accomplishments so the public can better understand where the Agency is today and where it is going in the future. Mr. Bridenstine agreed that such activities certainly need to be considered, and that there are many ways to ingrain the NASA presence into the U.S. and into global culture. There is much to do to inspire humanity, and NASA must not have a break in its 18-years of ISS off-planet operations in LEO.

# NASA Exploration Update

Mr. William Gerstenmaier, Associate Administrator (AA) for HEOMD, presented an update on NASA's human exploration program. He noted that his recent honor of receiving the Space News "Civil Leader in Innovation Award" actually represented a team award, and he acknowledged the pleasure of having his team's support. HEOMD continues to carry out three major SPDs; this is clear direction from the

Administration in going forward. The "sustainable" aspect of SPD-1 is most important for enabling human expansion across the Solar System. Despite how deeply the concept of Apollo is ingrained in American culture, it is not the speed of getting to the Moon, but building a sustainable architecture around it, with commercial and international partners, that is important. NASA is going to have to knock down some regulations to get there.

The path to moving human presence outward is based on developing incremental capabilities to move deeper into the Solar System, expanding the near-Earth economy to establish a presence in deep space, as is now being done in LEO, and making it immediately accessible to the commercial sector. The Gateway is being designed to provide an initial backbone crew transportation system, augmented with commercial crew transportation. HEOMD continues to follow its previously articulated strategic principles: fiscal realism, commercial partnerships, scientific exploration, technology push and pull, gradual buildup of capability, architecture openness and resilience, global collaboration and leadership, and continuity of human spaceflight. These principles are enduring. General Lyles asked if the concept of sustainability was embedded in the principles of fiscal realism and gradual buildup. Mr. Gerstenmaier affirmed that this was so, but added that he held as an internal philosophy the importance of not overpromising. Mr. John Borghese named other principles relative to fiscal realism, such as the open architecture that allows other partners to contribute, and commercial solicitations meant to discover what is commercially available (e.g., spacecraft buses) to meet NASA needs. Mr. Gerstenmaier noted that HEOMD is not forcing NASA requirements on commercial providers; any commercial entity can adopt the results of open competitions as long as they meet established, standard NASA interfaces. Dr. Meenakshi Wadhwa asked how HEOMD was accommodating science. Mr. Gerstenmaier said that commercial landers will fly some purely scientific payloads, and that HEOMD will piggyback and leverage some hazard avoidance and terrainrelative navigation technology demonstrations. Thus far, the synergy between Science and Exploration has been working very well. Mr. Gold commended Mr. Gerstenmaier's successful Broad Area Announcement (BAA) for the Gateway's Power and Propulsion Element (PPE), which was meant to leverage commercial efficiencies. Mr. Gerstenmaier said HEOMD would continue to use innovative approaches, while not undoing the reliabilities of existing technologies and rockets. He noted that the international partners have been very supportive of the Gateway, and the different way of doing business within a broader architecture. NASA has established international interoperability standards in preparing for deep space exploration, and now has an international docking standard. Three entities are building to that standard right now. The Gateway can be used by anyone building to these standards, which is a huge piece of the open architecture philosophy. Dr. Elisabeth Paté-Cornell asked about cybersecurity at the Gateway. Mr. Gerstenmaier said that NASA is still getting responses from around the world on how to deal with cyber controls.

Commercial cargo transportation is going well as NASA approaches the first commercial crewed missions to LEO (Boeing and SpaceX). Exploration Mission-1 (EM-1), which will be to a distant retrograde orbit around the Moon, is a demanding, first-of-a-kind mission, and will be un-crewed. Checkout and verification for EM-1 is under way. Related activities are parachute and recovery testing for the Orion capsule, and testing of 3-D printed components. The main engines were recently run at 113% for 100 seconds, a test that went very well. The second exploration mission, EM-2, is a high elliptical orbit, lunar fly-by mission and will be the first flight with crew. NASA is in the process of understanding the detailed engineering needs for Gateway, which will be three to five days away from Earth; this distance is farther than Apollo limits. Gateway will be sitting at the intersection of Earth's gravity well and the lunar gravity well, which is a good starting point for a variety of activities. The Gateway will also provide a thermal stable environment, in which science can look at both the Earth and the Sun. It also provides a unique vantage point for a single solar instrument that can measure energy going in and out of the Earth system, and for other sortie missions for the science community. Just as St. Louis is a stepping-off point to the West, the Gateway can be a stepping-off point to the rest of the Solar System.

There are two approaches for accessing the lunar surface: direct Apollo-style vs. accessing the lunar surface through Gateway. Gateway enables reusable lunar systems, enables long-term mission capabilities, establishes initial refueling capabilities that will be necessary for a Mars cruise, and deep-space testing of Mars-forward technologies. Reusability is the key piece, as opposed to speed. Mr. Borghese asked if there were other limitations to the Gateway. Mr. Gerstenmaier felt that Gateway has more complexity as it pertains to reusability and adaptability. It is also not optimal for any one location on the Moon. Gateway can be a safe haven for 30-90 days, and is not limited to the Orion stay-time in orbit; it can be a place to aggregate resources. Gateway also helps NASA back off from human rating requirements by distributing safety requirements across multiple elements. Asked if computing and avionics systems were taking sufficient advantage of rapidly changing technology, Mr. Gerstenmaier noted that HEOMD has been able to do this with ISS, and has been able to upgrade on the fly, and expects to do this with Gateway. The primary argument against Gateway remains the delay. In addition, Gateway can't go to a low lunar orbit, but it can be biased to either pole of Moon, and can transition positions with SEP (takes 150 days). These maneuvers are good practice for Mars operations.

EM-3 will be carrying the first habitable piece to Gateway. The outbound flight to the Moon takes five days, and the vehicle stays in NRHO for 11 days. EM-3 will help NASA to learn how to sail on gravity boundaries, thereby saving fuel. The related orbital mechanics problems can be farmed out to universities for possible solutions. The international community is interested in various components of Gateway (robotic arm, habitation module), and NASA is still actively soliciting for these components, holding everything from general agreements to soft commitments. Dr. Wadhwa asked if there were any plans for sample return analysis at the Gateway. Mr. Gerstenmaier said the question was still open; an on-site crew could select samples, for example, but it is expected that samples would be returned to Earth for analysis. Asked what sets the 30-90 day dwell time, Mr. Gerstenmaier cited economic constraints. Asked if there were any improvements in radiation remediation, Mr. Gerstenmaier said that while a Gateway storm shelter was planned, limiting exposure would be the initial strategy. Dr. Paté-Cornell asked what limited the timelines in the phases of development. Mr. Gerstenmaier felt the big unknown was fiscal realism, and took an action to go a little deeper in response. Mr. Mountain asked: if you double the budget, can you double or quadruple the 30-90 day stay?

Mr. Gerstenmaier thought there was some advantage in having a spacecraft that is sometimes robotically operated. Stay times are tied to SLS and Orion. International partners or commercial partners are also being queried for their views on the subject. The PPE is slated for a 2022 launch, for which HEOMD is evaluating proposals, and has structured the BAA to design to up to a one-year on-orbit operational life after launch vehicle separation. As soon as PPE is in place, science instrument payloads can be delivered. The notional Gateway build-up from 2022-26 will involve a mixture of NASA and commercial flights. This scenario allows functional capability all along the way, and a reasonable resistance to budget and other uncertainties. Today, NASA requires SLS to fly Orion. A single Orion flight can also carry a utilization module and crew, but SLS is not yet able to carry 25 metric tons.

There are several commercial companies working on habitation development: Lockheed Martin, Northrop Grumman, Bigelow, Boeing, and possibly Sierra Nevada. International partners also seem to find the open architecture very attractive. Lunar transportation technology development is being carried out through SMD, the Space Technology Mission Directorate (STMD) and HEOMD. Gateway enables a three-stage lunar architecture, comprised of an ascent element, descent element, and transfer vehicle. The descent element is the only throw-away component. All the masses are within the capabilities of commercial launch vehicles. The first demonstration of a human lander is scheduled for 2024, which will be designed for long-term exploration and utilization of the Moon. There will be 13 science cubesats on EM-1, one of which will land on the Moon; this latter planning element roughly fits within the current budget. Dr. Penina Axelrad asked how these future spacecraft would navigate. Mr. Gerstenmaier said that lidar and radar would be two means, but that HEOMD is looking at using GPS for some spacecraft around the Moon (on the near-side) as well as star-trackers and inertial measurement units (IMUs). Asked what will happen after commercialization studies come in on ISS utilization, Mr. Gerstenmaier said he would be asking each provider for sharable information, recognizing that there will be some intellectual property constraints. Any open data can be transmitted to the RPC quickly. There will be hybrid models as well. Mr. Gold asked if there were any issues that the RPC was missing. Mr. Gerstenmaier said that ISS is sometimes seen as free from export control restrictions, which is not the case. There are still some snags which arise from weapons system restrictions.

General Lyles thanked Mr. Gerstenmaier for his excellent presentation, and commended him on his recent induction into the National Academy of Engineering.

## Human Exploration and Operations Committee Report

Mr. Kenneth Bowersox, Chair of the Human Exploration and Operations (HEO) Committee, presented the committee report. With member Shannon Bartell leaving the HEO Committee, the committee is looking for new members with launch experience at NASA's Kennedy Space Center, program management experience at NASA's Marshall Space Flight Center, and legislative matters. At its last meeting, the HEO Committee discussed the various programs, Gateway, and PPE, and discussed the direct-to-lunar surface approach at length. One issue is there is no comparative mission. The HEO Committee devoted some time to distilling points in favor of Gateway, entitled "Why Gateway?" which was winnowed to a short list tailored to a general audience:

# Why Gateway?

"We've already been to the lunar surface – why not do something more challenging, which will develop capability to go beyond the moon?" The following points address this question:

- Gateway is for Mars exploration like Gemini was for Apollo a program to develop new capabilities that will be required to go further into our solar system, and to develop the partnership that was built on ISS.
- The cislunar orbiting platform (Gateway) isn't just about going to the lunar surface, or going to Mars, it's about both, and about going beyond.
- Gateway makes it possible to use of all of the capabilities available in the United States and international partner countries to further human exploration Orion, SLS, Commercial Launchers, International Launchers, International transport vehicles and future elements provided by international and commercial partners.
- Gateway allows different elements to be built and operated by different partners, providing multiple options, and minimizing chances that any one partner will be in the critical path.
- Gateway is not ISS around the moon. Gateway is intended to be procured a different way with much less cost more like commercial cargo than either commercial crew or Orion.

Mr. Bowersox presented a proposed NAC finding on the Gateway ("Lunar Orbiting Platform"), and briefly compared it to a previous finding that had been made jointly with the Science Committee. After deliberation, the Council approved the following finding to the Administrator:

Space Policy Directive 1 (SPD 1) tasks NASA to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. It also tasks NASA with returning to the moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.

To meet the exploration and science requirements which flow down from SPD 1, NASA has formulated a plan based on establishment of a lunar orbiting platform that will enable international and commercial partnerships, reusability of hardware to transport crews to and from the lunar surface, allow critical access to the lunar polar regions, reduce risk for lunar exploration crews by providing a safe haven, improve communications with spacecraft on the lunar surface, and provide valuable opportunities for scientific investigations, while expanding the knowledge base in the area of deep space maneuvering and solar electric propulsion required for travel to Mars.

#### The NAC strongly endorses NASA's plan for achieving the goals set forth in SPD 1.

General Lyles said he saw the new finding as the next level above the previous, and because there has been discussion of a direct-to-lunar approach, he thought it would be helpful and timely for the NAC to make a new statement. Mr. Hale thought it might be good to appoint a devil's advocate, as he had not heard a coherent discussion from the other side. Dr. Alan Epstein asked: is it a question of either/or? Or is there a large set of other things? Dr. Epstein suggested a "red team" might be useful for making the case for alternative architectures. Mr. Bowersox noted that the HEO Committee is usually pretty vocal, and that there was strong agreement that Gateway makes sense, but he acknowledged that it is complicated. However, explanation leads to acceptance. It is true that the NAC has not heard the whole story of the direct approach; however, it is known there would be costly and time-consuming changes to SLS and Orion in the case of a direct-to-lunar approach. Mr. Borghese felt that given the size of the Gateway, it would be a good idea to explore other ideas, given that it is often hard to admit that one is going down the wrong path. Dr. Patricia Sanders said she had to believe that NASA has spent time looking at alternatives, but that at some point it was necessary to make a decision. Mr. Borghese thought that Gateway should have an off-ramp. Dr. Epstein said, as Gateway is a large national commitment, that it might make sense to convene a workshop or a National Academy of Sciences (NAS) study, fairly soon, in order to have a public airing of people who think they can do better, and can subsequently give input to the HEO Committee. General Lyles said he personally supported the new HEO Committee finding, but that the NAC should state that it recommends a "red team" or a NAS study to compare Gateway to other approaches, to assure and inform the NAC. Dr. James Green, NASA Chief Scientist, commented that missing in the discussion are the initial requirements, and referred the NAC to the Transformational Lunar Science report. The report details the Moon's water deposits at either pole as well as the need for mantle samples from the South Pole's Aitken Basin. SMD also needs samples from the far side. At present, we know more about the surface of Venus than the back side of the Moon. If Gateway starts with those requirements, lunar requirements can be seen as a global problem that a flexible architecture can enable.

Mr. Bowersox said it was important to remember that NASA aims to fulfill SPD 1, which says "build a capability to go beyond." Is the NAC questioning SPD 1? Dr. Epstein felt it was more a matter of elucidating the scientific utility of the Gateway, while engaging the internationals and commercial industry. NAC does not seek to presuppose the answer; it just wants to help NASA make the case that it has considered all reasonably enunciated approaches. Can the NAC help NASA make the case with an open-forum workshop? A NAS study takes 18 months, far too long for assessing a program in development. Mr. Bowersox said that HEO Committee was pretty familiar with what's possible, and they unanimously supported Gateway. Moreover, people who want to get back to the Moon will be unhappy with Gateway and people who want to get to Mars will be unhappy with the direct approach. General

Lyles thought that the Gateway concept had taken SPD 1 well into account. General Lyles said that as a member of the UAG, he chairs the Exploration and Discovery Subcommittee, and thus had some ability to ask for a "red team" or workshop outside of NAC channels. Mr. Bowersox suggested a joint meeting with the HEO Committee and UAG might be useful. Dr. Wadhwa noted that a science exploration and discovery component should also be included.

Mr. Bowersox then introduced a proposed recommendation from the HEO Committee:

The NAC recommends that while working to implement improvements that have been recommended for programs like the James Webb Space Telescope and the Space Launch System, NASA should also take positive action to ensure that the policies which are within the agency's control, provide needed flexibility for program managers to enhance the agency's ability to continue its innovative and inspiring efforts in the exploration of Space. The first step in this process should be to solicit inputs from program managers on factors that would help them better meet all their obligations.

Mr. Bowersox described the background for the recommendation, explaining that there has been a lot of pressure on NASA Program Managers, some of it due to Continuing Resolutions and budget uncertainties that are eating into management's flexibility to deliver their programs. The HEO Committee is merely recommending that NASA talk to their Program Managers to determine what they need. Mr. Borghese thought that this was an important recommendation, as budget problems tend to quash innovation. Dr. Sanders commented that in large, complex state-of-the-art programs, it is hard to be constrained when the program's purpose is to push the envelope. Dr. Mountain said that having watched what happened with the James Webb Space Telescope (JWST), the question is what type of recommendation is actionable. Mr. Bowersox said that each Program Manager has a different need: accounting systems, for example, for the SLS and Orion programs. Dr. Epstein commented one of the best contributions made by NASA is the Technology Readiness Level (TRL) scale. If honestly enforced, the scale can save much money by helping to identify schedule costs and impacts, and by giving a good idea of risk as well. It call comes down to risk, and having a reserve. Dr. Paté-Cornell said that the question of balance of risk and cost is an important component for Gateway. General Lyles suggested that the HEO Committee revise the recommendation, making it relevant to lessons-learned for the James Webb Space Telescope (JWST). Mr. Hale thought that putting JWST into the recommendation would result in more processes and procedures from NASA. In a later discussion, the NAC tabled this HEO Committee recommendation to another meeting.

General Lyles tabled a discussion about another HEOC recommendation regarding the ISS until the following day.

## Technology, Innovation and Engineering Committee Report

Outgoing Chair of the Technology, Innovation and Engineering (TI&E) Committee, Dr. William Ballhaus, gave his report by phone. The TI&E Committee's meeting took place on December 7, 2018. Mr. James Free will be taking over as the new Chair in January 2019. SPD 1 continues to present an opportunity for NASA's technology program, and it informs technology investment. There is now an opportunity to develop a baseline architecture and project plan to return American astronauts to the moon for long-term exploration of Moon and Mars. Dr. Ballhaus hearkened back to Norm Augustine's quote on the importance of NASA doing "grand" missions," which spurs technology development, and demonstrates U.S. leadership. The TI&E Committee continues to assert that NASA needs cutting-edge technologies to undertake its missions. In recent decades, there had been steady erosion of technology budgets at NASA. To reverse this decline, NASA established the Office of the Chief Technologist (OCT) in 2010, and the Space Technology Mission Directorate (STMD) in 2013, which rebuilt early TRL development across the agency. Cutting technology had also decimated NASA's historically fruitful interactions with universities, however STMD has since reestablished its ties with the university community through the Space Technology Research Grants (STRG) program. The TI&E Committee met with a group of STRG fellows at the Jet Propulsion Laboratory (JPL) in 2015, and came away quite impressed with their abilities. The STRG portfolio now includes 595 awards at 107 universities, and represents a great investment in human capital for NASA and its contractors in the future. Dr. Ballhaus briefly reviewed the TI&E Committee's July and November 2016 observations on NASA's revived technology program, and a rekindled interest in NASA among student engineers. General Lyles noticed a lack of Historically Black Colleges and Universities (HBCUs) in the briefing chart on STRG fellows. Dr. Ballhaus said he made several trips with the Administrator, who is sensitive to the matter and is aware of the associated requirements.

One of the TI&E Committee's March 2018 findings noted that major missions had been enabled by NASA's technology investment program, and emphasized the need for fencing off technology "seed corn" via STMD. If STMD is eliminated, the Committee is concerned as to how would NASA might assure that its technology program does not erode. Dr. Ballhaus felt that Mr. Steven Jurczyk, STMD Associate Administrator, has a good handle on the situation. An August 2018 NAC recommendation on this subject had been submitted to the NASA Administrator, within the historical context of the 1958 Space Act, to encourage preservation of the U.S. as a leader in aeronautics, and space science and technology.

Dr. Ballhaus expressed his gratitude for his time with the NAC. General Lyles thanked Dr. Ballhaus for his service. Dr. Epstein said he would always remember Dr. Ballhaus as "a good CFD guy," and observed that the Space Act of 1958 had its origins primarily in aeronautics.

## Regulatory and Policy Committee

Mr. Mike Gold, Chair of the Regulatory and Policy Committee presented a briefing on the Committee's first proceedings, noting that while it is a broad and diverse group, it was able to reach consensus on its observations, findings and recommendations, and was able to leave corporate parochialism at the door. Mr. Gold presented two Regulatory and Policy Committee recommendations pertaining to ISS and export controls. The first recommendation read as follows:

NASA should make it a priority to lead an effort in collaboration with the Department of State and the Department of Commerce to expand the exceptions to the U.S. Munitions List (USML) and special provisions within the Commerce Control List (CCL) provided to the ISS to explicitly include the Lunar Gateway, commercial habitats within the ISS program, NASA-led missions, and private sector platforms, regardless of location, including suborbital, orbital, cislunar, and deep space, which would benefit from the same relief from export control provisions that the ISS enjoys.

The second recommendation read as follows:

Per the 2018 National Defense Authorization Act, when asked to review export control licenses or Commodity Jurisdiction Requests, NASA should strive to avoid unilateral controls whenever possible.

Mr. Bowersox felt that the first recommendation needed to be actionable by NASA. Mr. Hale felt the initial wording to be too weak, and NASA should make it a priority. General Lyles said he would take the first recommendation to the NSpC as an input. Mr. Borghese and Dr. Axelrad thought that both recommendations seemed to go beyond NASA. General Lyles recommended referencing the National

Defense Authorization Act (NDAA), and rather than a second recommendation, proposed it as a finding from the NAC that supports the NDAA. After further deliberation, the Council approved both recommendations to the Administrator.

Mr. Gold presented a third recommendation, on the treatment of Intellectual Property (IP) at ISS. Dr. Epstein felt that IP considerations constitute a complicated and subtle issue that has ramifications throughout NASA and the Federal Government. Mr. Gold argued that ISS is a unique situation that enables the U.S. to maintain leadership in LEO. General Lyles asked Mr. Gold modify to make minor edits, and asked that the issue be tabled for later discussion.

Mr. Gold then presented fourth and fifth recommendations regarding an international scientific body, the Committee on Space Research (COSPAR), that were combined into one recommendation after some deliberation:

NASA should establish a multi-disciplinary task force of experts from industry, the scientific community, and relevant government agencies, to develop U.S. policies that properly balance the legitimate need to protect against the harmful contamination of the Earth or other celestial bodies with the scientific, social, and economic benefits of public and private space missions. The recommended multi-disciplinary task force should be tasked with producing a detailed policy, provided to a joint session of the NAC Regulatory and Policy Committee, the Science Committee, and the HEO Committee, that will describe best practices for the Administration, the science and research community, and private sector, to protect against harmful contamination and adverse changes in the environment of the Earth. The multi-disciplinary task force should also explore the use of the term 'Planetary Protection' relative to other terms utilized in the Outer Space Treaty.

Dr. Thomas Zurbuchen, Associate Administrator for NASA's Science Mission Directorate (SMD), commented that the recommendation was very much aligned with recent guidance from the National Academy of Sciences, as planetary protection techniques, as well as the science behind them, have evolved considerably since the original COSPAR guidelines were issued. Revising the guidelines with the involvement of all the stakeholders is the right thing to do. All the voices need to be present during the discussion in order to strike the right balance, to protect great future science, and to protect life on Earth. COSPAR's current President, Dr. Lennard Fisk, the first American president of COSPAR, was present at the NAC meeting and was invited to comment. He stated that planetary protection guidelines need to be updated to accommodate industry interest, human spaceflight, and science. He noted that all COSPAR guidelines for Mars exploration were written by the U.S., Space Studies Board of the National Academy of Sciences, which has led the world in this respect. Dr. Fiona Harris, speaking by phone, referred to a report originally commissioned by the former SMD Associate Administrator, Dr. John Grunsfeld, which contained many findings and recommendations similar to those of RPC. Additionally, she pointed out that the term "planetary protection" is a term that NASA had developed, and everyone knows what it means. Dr. Zurbuchen felt that an ad hoc review of the revised guidelines would be sufficient. After further deliberation, the Council approved the COSPAR recommendation.

Mr. Gold presented a sixth recommendation on guaranteed access to ISS for company-owned facilities and their products aboard the ISS. Mr. Bowersox stated that such access cannot be guaranteed – other priorities often take precedence. Dr. Epstein noted that NASA owns ISS, and has stewardship of the nation's space presence; ISS cannot be ceded to someone who has bought in. ISS is a national facility. Mr. Gold said that NASA is looking for advice on how to prioritize these activities, and that one metric NASA should look at is whether there has been an investment in the NASA facility. General Lyles felt that a more limited expression would be a good replacement for "guarantee" and tabled the discussion to a later date.

# STEM Engagement Committee Report

Dr. Aimee Kennedy, Chair of the STEM Engagement Committee, presented a report. The Committee held its first meeting as a "Committee" – recently upgraded from Task Force status – on December 4, 2018, during which it reviewed the NASA Office of STEM Engagement's significant work over the last year, particularly its great progress in its Business Services Assessment (BSA) study.

Dr. Kennedy put forth the first Committee recommendation on compliance with the five-year Federal STEM Plan. Dr. Kennedy explained the criteria for compliance, and that NASA is being asked to implement the Plan within the confines of the existing budget. General Lyles asked that the recommendation be changed to a finding that endorses the Plan, because NASA has already been mandated to participate. After Council deliberation, the final wording of the finding that was approved by the Council is as follows:

The Council endorses the NASA Office of STEM Engagement's participation in the Federal STEM Plan, ("Charting a Course for Success: America's Strategy for STEM Education, December 2018"). As a result of its work, NASA has a unique opportunity to inspire the country, and to broaden participation in the future STEM workforce. The agency has extensive involvement in leadership of the plan. Administrator Bridenstine co-chairs the Committee on STEM Education (Co-STEM), and Associate Administrator Kincaid co-chairs the Federal Committee on STEM (FC-STEM). As a Federal agency, NASA is required to participate in the Federal STEM Plan, and NASA agreed to be a contributor for three of the nine objectives in the Plan.

Dr. Kennedy then presented a Committee finding. After Council deliberation, the final wording of the finding that was approved by the Council is as follows:

The Council finds that Office of STEM Engagement is taking steps in identifying and amplifying NASA's unique achievements. Information has been presented and progress has been made on the following topics:

- Space STEM forum
- Website redesign
- Aligning with and co-funding STEM activities with the Space Technology Mission Directorate (STMD)
- Consolidation of program management of Minority University Research and Education Program (MUREP), Established Program to Stimulate Competitive Research (EPSCoR) and Space Grant for the express purpose of increasing knowledge sharing across the programs
- Integration of STEM engagement activities across the three programs above and NextGen STEM

Dr. Kennedy presented a second Committee recommendation on how to capture the interest of young students, and identifying the factors that make people persist in STEM:

The Office of STEM Engagement should create a deep and comprehensive document that describes what we know about spark, STEM engagement, and motivation, and use it to create the foundational evidence for the Office.

Dr. Wadhwa commented that the expertise to determine this "spark" phenomenon does not reside at NASA. NASA Associate Administrator for STEM Engagement Kincaid commented that the recommendation is not intended for NASA, per se, and that the "we" of the recommendation refers to the body of research on what is known about STEM motivations. General Lyles asked Dr. Kennedy to reword the recommendation to reflect these thoughts and table it for presentation at a later time.

Dr. Kennedy presented a Committee observation, and General Lyles asked that the observation be elevated to a finding. Mr. Borghese suggested omission of the budget consideration. Dr. Epstein asked to define the success criteria for this activity for the NASA organization. General Lyles said he would discuss the unspoken nuances of the budget with the Administrator. After Council deliberation, the final wording of the finding that was approved by the Council is as follows:

The Council finds that the statute that governs the Office of STEM Engagement appears to limit its ability to nationally scale their programs and outreach. The majority of the budget allocated to the Office of STEM Engagement is partitioned to specific categories of institutions and programs. The NAC STEM Engagement Committee plans to learn more about the current efforts of the Office to achieve national scale, and recognizes that understanding evidence-based practices for sparking STEM engagement and motivation is a critical first step in the discussion around scale.

# <u>December 11, 2018</u>

# Call to Order, Announcements

General Lyles opened the meeting. Ms. Rausch reiterated administrative comments.

## Remarks by NAC Chair

General Lyles asked for comments around the table. Dr. Epstein observed that NASA is at a pivot point in national space effort, as it transitions from ISS to Moon-based NASA activities, and as it sees the rise of successful commercial space development; the next five years are richer in potential for the Agency than in the recent past. Dr. Wadhwa said the two new committees were off to a great start, and that the COSPAR discussion will be of great value moving forward. Mr. Borghese said he was concerned about the limited time for discussion, and wanted to be more thorough. General Lyles noted that the NAC had been constrained on this meeting, and pledged to think about how getting issues circulated ahead of meeting times to allow for adequate discussion. Mr. Hale said it was a privilege to be part of the process, and hoped that the NAC was doing a good job of representing more than just space groupies; the NAC must talk about safety, climate, etc. and hear out people who possess alternate viewpoints. General Lyles agreed that the NAC needs to expand beyond an in-house perspective. Mr. Bowersox remarked because so much is going on, it may be a good time to think about having more telecons in between face-to-face meetings. Dr. Mountain referred to Dr. Ballhaus' legacy, noting that the question remains about technology: how will NASA ensure the health of its technology programs if STMD is eliminated. Technology is just as important as science in the NASA scheme of things. Without engineering and technology, science is just philosophy. Dr. Paté-Cornell echoed General Lyles' comments on hearing diverse commentaries, and how important it is to learn how to engage and encourage the younger generation. Mr. Gold supported the idea of hosting a telecon prior to the NAC meetings, and thanked the NAC for its support of the COSPAR discussion.

#### Public Input

No comments were noted.

#### NAC Staff Recognition

General Lyles announced that Ms. Marla King is retiring after 36 years as a Federal employee, and 15 years with the NAC. On behalf of all of the NAC members, he thanked her for her dedicated NAC service, and extended the Council's best wishes for happiness in retirement and in all her future endeavors.

## Science Committee Report

Dr. Wadhwa, Chair of the Science Committee, briefed the NAC on the Committee's last meeting in early November 2018. The Earth Science mission, ICESat-2, launched successfully on the last available Delta II rocket, on September 15, 2018. The satellite employs a laser instrument that measures the height of ice cover on Earth. Terrestrial ice reserves are changing rapidly, a factor important for climate change studies. The Suomi National Polar-orbiting Partnership (NPP) satellite aided in disaster recovery efforts by imaging power outages during the aftermath of 2018's Hurricane Michael, one of the most powerful hurricanes to make landfall in many decades. The Heliophysics Division (HPD) mission, the Parker Solar Probe, launched in August 2018, and acquired first light from the four-instrument suite on September 19, 2018. On October 29, 2018, the Probe approached the Sun within a radius of 27 million miles, the closest approach to the Sun. The Probe is also the fastest spacecraft, and will be important step forward for understanding the fundamental physics of stars, solar activity, and mass loss. Dr. Eugene Parker, the mission's eponymous tribute, is still living. In an example of the breakdown of division silos within SMD, the Heliophysics Division is also enabled by the Planetary Science Division by such missions as Venus Express, which enhance the understanding of interplanetary magnetic clouds. Mr. Borghese asked how SMD determines where to invest in future research. Dr. Wadhwa described the National Academy of Sciences' Decadal Survey process, which defines the high-priority areas that NASA should invest in. Various Decadal Surveys for the subdisciplines of SMD are now at critical points. Dr. Zurbuchen interjected that SMD is trying to drive toward objectives through the Decadal Survey process while investing in a broader portfolio that is often off-target; some of the biggest discoveries have been side projects. This reflects the balanced portfolio of NASA science.

The Kepler mission received its last commands on November 15, 2018, after having discovered thousands of exoplanets during its nine-year mission; 70% of known exoplanets were discovered by Kepler. There is still data to be analyzed, with 2900 candidates yet to be confirmed. Kepler and the Hubble Space Telescope may have resolved the first exomoon; JWST will be able to resolve and confirm the existence of other exomoons in the future. InSIGHT had a successful landing on Mars, and will deploy a seismometer and thermometer to study the interior structure of the planet over an operational lifetime of two years. The spacecraft Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-Rex) is now at the asteroid Bennu, where its instruments can already see some compositional differences. At a recent press conference, researchers announced the detection of hydrated minerals; the mission will return physical samples to Earth in 2023. These samples will be informative for the composition of volatiles and water in the early Solar System, with implications for habitability and the origins of life on Earth. Sample retrieval will be carried out through a pressurized touch-and-go maneuver, which may be able to retrieve as much as 1kg, with a minimum requirement of 60g.

The Science Committee heard an update on JWST from Mr. Greg Robinson, SMD's Deputy Associate Administrator. The telescope completed an acoustic test for the Spacecraft Element, and is now in vibration testing. Dr. Zurbuchen commented that JWST has a very different team in place now, but there

are still some mountains to climb. Dr. Wadhwa noted that the SC discussed the report from the JWST Independent Review Board. A new review will be held in March 2019. General Lyles said that the JWST situation shows that, clearly, there are lessons to be learned programmatically. Dr. Zurbuchen observed that these lessons are different at each level of the hierarchy. After having spent much time with Mr. Gerstenmaier, and comparing notes, he added that lessons-learned are to be taken as an ongoing, living thing. Asked if there are servicing options for JWST, Dr. Zurbuchen explained that it would take 26 days to reach JWST at its dwelling place at L2; there is no means of sending a service mission at present. There has been an analysis that revealed that it is possible to refuel JWST, but right now the program is focusing on getting an asset on orbit that works. The mission will image the 26-day cruise to see what's happening. L2 is beyond the Moon, and cruise imagery may prove informative for Gateway and other exploration missions.

Dr. Wadhwa reported that the four SMD divisions held their annual Government Performance and Results Modernization Act (GPRAMA) reviews, in which all science focus areas were rated "green."

The recent Science Committee meeting had focused on three cross-cutting priorities: the Decadal Survey status of the division in SMD; interdivisional approaches and implementation; diverse teams and creating safe workplaces; future of autonomy in NASA meetings; and public-private partnerships. The Earth Science and Astrophysics Decadal Surveys are coming up, and the community is trying to get a handle on informing the new Surveys. The Committee also recognized that establishing diversity and safety will be an ongoing process, as Dr. Zurbuchen has stated: the matter is complex and not "one and done." The Science Committee had some reports from the SMD Division Directors on interdivisional activities, indicating that many cross-disciplinary activities are already under way. In the matter of Earth Science Decadal Survey implementation, while long-time Earth Science Division Director Dr. Michael Freilich is retiring, the Science Committee was relieved to know that he leaves the Earth Science Division in very good hands. Dr. Zurbuchen noted that the vacated position will be filled via an open competition, and not an appointment. SMD has taken a month or so, and met with community leaders to solicit recommendations, which has yielded a significant number of candidates. The position is open till early January 2019. Dr. Zurbuchen said he had no worries about the vitality of the Earth Science community, and that Ms. Sandra Cauffman has proved a very strong leader in the interim period.

The Committee heard a report on safe environments and diverse teams, given by Dr. Meg Urry. SMD recognizes the linkage between diverse teams and safe environments, but notes that there are still issues with women and minorities in STEM fields, particularly in terms of retention. Mr. Hale and General Lyles expressed shock at the statistics that were presented, and the prevalence of abuse in the sciences. Dr. Michael New also briefed the Science Committee on efforts that are already under way at NASA to create environments in which women and minorities were adequately supported. It is clear that interventions are needed, because bias is still very much present against women and minorities. Dr. Zurbuchen said it was important to note this will take some time to change; the issues are too complicated, but SMD is working on it. Dr. Wadhwa added that there are recognized best practices, and that diversity and inclusion are two different things. The Science Committee took an action to look at other best practices, and would be returning to the SMD Associate Administrator with recommendations. Asked if the barriers were unique to the science community, Dr. Wadhwa said that STEM is particularly vulnerable, but there is nothing specific to SMD in that regard. Dr. Axelrad commented that because they are more visible within the science community, publication statistics tend to work against women and minorities, and undermine the perception of merit. Dr. New added his own findings from inferred-gender studies of the 2017 ROSES competition, which found 25% of proposals with female names, in fields where 40% of PhDs are given to women. In Discovery class proposals, only 10% of Principal Investigators were found to be female. There was also great divergence among the four SMD Divisions; the Planetary Science Division is heavily female, as opposed to other Divisions. General Lyles suggested

that the Science Committee look at what the National Academy of Engineering and the Department of Defense are doing in this area.

The Science Committee heard briefings on autonomous solutions and robotics, and about the growth in the behavioral complexity of planetary rovers. SC made several observations on the subject, and took an action to bring together peers to discuss autonomy and public-private partnerships in order to bring about mission-changing technologies. Mr. Gold commented that there many artificial intelligence (AI) activities in the intelligence community, and said he would be happy to do some outreach. Mr. Borghese commented that as AI is making such great strides, he imagined that robotic servicing can become a cost-saver. Dr. Zurbuchen commented referring to the next-generation telescopes that the problem is in getting away from the cost models. The convention still states that telescope costs are directly related to the size of the mirror; he agreed there was a need to spin-in new techniques and technologies to alter conventions.

Dr. Wadhwa presented two Science Committee findings for transmission to the SMD Associate Administrator. The first finding read as follows:

The Science Committee finds that it is important to balance disciplinary depth and interdisciplinary breadth in the NASA Science Mission Directorate (SMD) implementation of each of the National Academies' decadal surveys on astrophysics, planetary science, heliophysics and Earth science. Core to this is to determine how to acknowledge and reward those who undertake SMD inter-divisional and inter-disciplinary collaboration. In support of excellence and innovation, the Science Committee also recognizes the potential value of commercial partnerships, inter-agency partnerships and international partnerships to achieving the priorities within the decadal surveys.

The second finding read as follows:

The Science Committee commends NASA Science Mission Directorate (SMD) for the effort it is undertaking on the serious matters of diverse and inclusive teams and safe environments. Given that follow-through is key, the Committee appreciates SMD's commitment to translate intention into action. The Committee has formed an informal team and will deliver information on best practices and lessons learned from other organizations that SMD can utilize.

After deliberation, the NAC approved the two findings. General Lyles said they would be reflected in the NAC's report to the NASA Administrator, and that he really appreciated Dr. Zurbuchen's contributions during the discussion. He added that the Department of Defense has been using the term "augmented intelligence" in lieu of artificial intelligence, and he felt that this term should be incorporated into future discussions.

## Aeronautics Committee Report

Mr. John Borghese, Chair of the Aeronautics Committee, presented an update. Aeronautics Committee membership includes representatives of the latest ideas in transportation (Uber, autonomous vehicles, drone flight). The most recent Aeronautics Committee meeting explored noise modeling and technology solutions, autonomy, subsonic technology development strategy, and air traffic management (ATM).

In Aeronautics recently, the question is how to focus NASA's technology investment strategy. The industry is studying the limits of package delivery, via urban air mobility, of 55 to 12,000 pounds, over ranges of 25 to 400 nautical miles. There are different approaches throughout the industry, with no standards yet. Research areas relevant to all concept vehicles that are not being concentrated on by industry, and worthy of NASA attention, are safety and airworthiness, and noise and annoyance. The

Aeronautics Committee feels it is imperative that NASA continue to improve safety. Between 2009 and 2018, there were no fatalities in U.S. air carriers. Dr. Epstein noted that air travel in the U.S. is four times safer per kilometer/mile travel than trains or cars; that is a five-year running average. Mr. Borghese noted that in general aviation, worldwide, an average of one person dies per day.

At NASA, studies on noise and annoyance are under way. At NASA's Langley Research Center, the focus is on building high-fidelity computational fluid dynamics (CFD) models that can be used by industry for prediction and validation for vertical take-off and landing vehicles (VTOL), particularly for rotor blades. It has been found that noise can be reduced by positioning and phasing rotors, and that airway approaches can also be used to reduce noise and annoyance. Dr. Paté-Cornell asked at what stage of autonomous operation is cyber vulnerability introduced. Mr. Borghese said that vulnerabilities were located throughout the system, depending on connectivity, even if air-gapped.

Mr. Borghese presented a finding for transmittal to the Aeronautics Research Mission Directorate (ARMD) Associate Administrator. During the Council deliberations, Dr. Epstein commented that safety is critical and rightly a government activity, and was surprised that NASA picked the tiltrotor, because of the current military and commercial effort. NASA studies on tiltrotor are less valuable than NASA teaching people how to do it. Maybe think about the wording of the finding. Mr. Borghese agreed that the evaluation of probability is missing, and he would add this to the finding. General Lyles said he was willing to accept the mixed nature of the finding. The Council approved the following final wording for the finding:

The Aeronautics Committee applauds the Rotary Vertical Lift Technology (RVLT) project initiative with a focus on these two very critical areas needed for acceptance of Urban Air Mobility (UAM): noise and safety. The Committee offers the following suggestions. The ability to accurately model noise generation and its mitigation is particularly important in the design development of rotors for wide range of operations. There is a significant amount of work being performed around the world including Original Equipment Manufacturers on noise modeling and design for low noise. NASA could leverage this effort. A particular area in which NASA could sad differential value is in understanding and assessing public acceptance and perception of noise generated by air vehicles that will be used in UAM. For example, what is the most annoying part of the noise when there are many rotorcraft flying simultaneously in the vicinity. This topic could present an opportunity to engage K-12 students possibly as part of the NASA grand challenge.

Safety of vehicles in UAM is of critical importance and NASA could play a significant role in this area. The Committee suggests performing a Failure Mode Effects and Criticality Analysis (FMECA) including probabilities by component on several reference vehicle architectures. One project could be analysis of the propulsion system starting with a tiltrotor and including the complete powertrain with and without cross winds. Determining the safety level that not only ensures safety but also meets the public's perception on what is required on safety would benefit the industry. The development of a model that allows analysis of various parameters like safety and noise would allow designers to test innovative designs of air vehicles for UAM.

Addressing the global growth in aviation, wherein it is estimated that there will be a doubling of passenger trips by 2036, Mr. Borghese noted that international interests are continuing to invest heavily in subsonic transport market and technology. Mr. Borghese noted that the Chinese are now working on the 929 prototypes with the Russians, and are investing heavily to become competitive in the future, underscoring the need for the U.S. to remain ahead of the curve. Take-off and landing are the bottlenecks; changing one of the routes to metroplex into New York City took 7 years, due to mostly noise-related issues. Dr. Epstein commented that some subsonic-level metrics are astonishing goals, technically, as in a fuel consumption reduction of 40-50%. But noise is especially hard. The Boeing 707 produced 120dB

when it was introduced; the same size jet now runs at about 85dB. The biggest impediment is the ground and air side; we cannot build new airports and new runways without substantially reducing noise on takeoff and approach. NASA has established a testbed for hybrid aircraft/electric air engines with tens of megawatts and needs to build and test and see if it makes sense.

Mr. Borghese presented a second finding for transmittal to the ARMD Associate Administrator:

The Aeronautics Committee recognizes that there are thermal management opportunities where NASA can contribute as one of the biggest new challenges in designing all-electric or hybridelectric aircraft is heating and cooling of the electric powertrain components. The Committee suggests NASA consider the innovation that currently exists in the automotive industry in terms of tools. There is a gap in tools and this an opportunity for innovation that NASA could fill. The Committee believes that this might be a good area for collaboration with universities and industry. Another important area is battery cell/pack architecture and how it connects to vehicle-level high voltage architecture to meet aviation standards. Additionally, all-electric aircraft will require innovative design work to make battery packs that are lightweight with adequate thermal management. Other methods for electric energy storage, including fuel cell technology, for example, should also be considered. Universities could be of help in the development of needed tools and models and by rapidly testing of their fidelity through measurements on additive manufactured parts. Issues that could shape the future of subsonic flight, such as predicted climate change-induced atmospheric behavior should also be examined.

After Council deliberation and revision, the Council approved this finding.

Mr. Borghese addressed the subject of assured autonomy for aviation transformation, a crucial subject for the future. It is going to take a long time, and it must be made safe and certifiable. It has been recommended that the Aeronautics Committee connect with the Defense Advanced Research Projects Agency (DARPA) on the issue. Mr. Hale said he was concerned that autonomy could decrease safety in the short term, citing a recent incident that caused the loss of an aircraft. Dr. Epstein commented that drones do not have to be as safe as aircraft – they in fact need to be much be safer. There is no accident rate that is acceptable because there are too many drone flights that would need to be in the air at once. The technology needs another quantum leap to allow integration of uncrewed aircraft into the national air traffic management system. Autonomy might meet that need partially; the military has proved out some of these instances. Mr. Borghese regarded flying Ubers as a far-out vision, and that for the foreseeable future, these vehicles will be crewed. There is still a lot of debate over the role of autonomy. There are not enough pilots to crew the aircraft that will be coming along in the next 10-15 years. Autonomy could be a way to augment the skills of pilots. Mr. Bowersox commented that it takes more (human) skill to recover from an autonomous system failure than from a conventional system failure. Dr. Epstein stated he was hearing a need for more research.

Mr. Borghese presented a third finding for transmittal to the ARMD Associate Administrator. During the Council deliberations, it was noted that the gist of the finding is that if the U.S. does not tackle autonomy, the rest of the world will. The Aeronautics Committee would also would like to see a detailed plan on how to certify an autonomous system; NASA needs to socialize this concept, and there needs to be an understanding of the acceptance level and the cybersecurity issues. In addition, one Committee member lamented that she cannot keep PhD computer scientists in academia, because they get wooed away by higher salaries. How can NASA retain them? Technology is one way to excite students and keep them. General Lyles asked Mr. Borghese to convert part of the finding into bullets. The final wording of the finding is as follows:

Autonomous aircraft and related airspace operations and management enable emerging aviation capabilities in areas where the United States needs to maintain global leadership. The Aeronautics Committee offers the following suggestions:

- NASA can assume a fundamental role as the conduit between industry and the Federal Aviation Administration (FAA) for certification requirements and the verification and validation approach.
- Engage FAA early because autonomy is a disruptive concept to the standard DO-178C software certification process.
- Develop cyber security requirements which are not being addressed sufficiently by industry and are needed for safe operation.

The Committee expressed concern about the flow of talent from aerospace and universities to the to the broader tech industry. Engineers with autonomy and artificial intelligence backgrounds need to be enticed to enter and remain in the aerospace arena. The excitement generated by emerging urban air mobility where NASA is working is an area that generates interest to attract and retain these engineers in aerospace.

# Mr. Borghese presented a fourth finding for transmission to the ARMD Associate Administrator:

The Aeronautics Committee applauds NASA in exploring the future of air traffic management (ATM) needed to be viable for the significant increase in air travel in both conventional routes, new air mobility solutions, and unmanned vehicles. The Committee recommends exploring the potential of federated systems operated by third party service organizations. The NASA Grand Challenge is an opportunity to test some of these ATM-X approaches. Transition from the existing, very safe air traffic management system to the future ATM-X concepts needs to be examined as well. The Committee suggests that the design of the system takes into account seamless integration into the current system.

The project "Integrated Demand Management" (IDM) has shown promising results to the Federal Aviation Administration (FAA) and industry allowing a path to transition. IDM is the type of NASA research that is not well known outside of the aerospace sector but offers benefits to the current air traffic management system and the flying public.

After deliberation and revision, the Council approved this finding.

In closing, Dr. Mountain and Dr. Axelrad both noted a lack of diversity in the Aeronautics Committee current membership.

## Council Discussion and Final Wrap-up

General Lyles agreed to reserve the Regulatory and Policy Committee recommendations that are less time-sensitive to another time. Mr. Bowersox revisited the NAC's prior discussion about direct options to the lunar surface, and said he thought that the HEO Committee is too closely identified with NASA, as well as the NAC, which is something to think about. He encouraged General Lyles to more closely engage the National Space Council and its Users' Advisory Group to talk about alternative architectures. General Lyles felt that a workshop held through the National Academy of Sciences would be an appropriate way to hear from a broader audience. Mr. Bowersox felt that the HEO Committee chart comparing the Gateway and direct-to-lunar approaches could be modified to reflect some substantive changes in Constellation and SLS evolution. General Lyles thought the chart presented only negatives about lunar-direct and positives about Gateway and needed to be fleshed out further, and to enlarge the

connection to SPD-1. Dr. Wadhwa added that the science aspect needed to be included. Mr. Bowersox said there has also been a lot of internal work at NASA that is not widely known, and which should be expressed openly. With the SLS design, a direct-to-Moon approach takes a couple of launches, and gets closer to the delta-v requirement for the Gateway approach.

Mr. Bowersox referred to recent Soyuz anomalies and a Soyuz launch abort on October 11, 2018, and noted that the event did not end in tragedy because the Russian system is redundant and well-designed. NASA has similar escape systems for its Commercial Crew vehicles, and hopes to be able to recover as well. The Soyuz 55S hole that was discovered in August 2018 was successfully repaired, and the module will be disgarded after re-entry. Mr. Bowersox briefly reviewed ISS studies on external corrective maintenance trends, noting that performance has been a lot better than predicted on ISS, and that command and data handling is also much improved, due in part to ground testing. He hoped to have the results of a NASA research announcement on the ISS transition by the next NAC meeting.

Mr. Bowersox referenced a proposed HEO Committee finding on the ISS from July 2017, noting not much had changed. General Lyles said the NAC will learn a lot from the Broad Area Announcement (BAA) and suggest the finding be tabled pending BAA results, maybe via teleconference. Mr. Borghese thought that the proposed transfer of ISS to a commercial consortium has become increasingly problematic. Mr. Bowersox referred to an existing engineering analysis that indicates some ISS modules can last past 2028. Mr. Gold and Dr. Axelrad felt the NAC should issue a recommendation on a potential gap in LEO operations. Dr. Sanders said that the NASA Aerospace Safety Advisory Panel (ASAP) will be addressing this issue in its upcoming *ASAP Annual Report for 2018* which will be released soon.

Mr. Gold noted that the Regulatory and Policy Committee had several additional time-critical proposed recommendations for Council consideration at this meeting. The first recommendation pertained to use of the NASA logo. Following deliberation, the Council approved final language of the recommendation as follows:

The Council recommends that NASA conduct a comprehensive review of its contracts, Space Act Agreements (SAAs), and other legal vehicles to identify programs and partnerships wherein i) the contractor/partner should be permitted and encouraged to use the NASA logo in association with any publicity related to the activity, and ii) NASA should be permitted and encouraged to use the contractor's logo in association with any publicity related to the activity.

Another Regulatory and Policy Committee time-critical proposed recommendation pertained to promotional activities at NASA. Following deliberation, the Council approved final language of the recommendation as follows:

The Council recommends that NASA examine the possible public benefits and any risks of spacebased promotional activities on rockets, spacecraft, hardware, and/or modules, taking into account historical insights.

General Lyles reiterated that the NAC would hold the Regulatory and Policy Committee recommendations on Intellectual Property, perhaps for a later teleconference. Dr. Wadhwa requested that the Council plan for its next meetings at least a year ahead. General Lyles noted that this would be a NAC goal for 2019.

General Lyles adjourned the meeting at 12:05 pm.

# APPENDIX A

# AGENDA

# NASA ADVISORY COUNCIL

# NASA Headquarters Program Review Center, Room 9H40 Washington, DC 20546

# December 10-11, 2018

# **PUBLIC MEETING**

#### Monday, December 10, 2018

1:30 pm	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
1:35 pm	Welcome and Introductions by NAC Chair	General Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council
1:45 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	Break	
3:30 pm	Human Exploration and Operations Committee Report	Mr. Kenneth Bowersox, Chair
4:00 pm	Technology, Innovation and Engineering Committee Report	Dr. William Ballhaus, Chair (virtual)
4:30 pm	Regulatory and Policy Committee Report	Mr. Michael Gold, Chair
5:30 pm	STEM Engagement Committee Report	Dr. Aimee Kennedy, Chair
6:00 pm	Adjournment	

# Tuesday, December 11, 2018

9:00 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
9:02 am	Remarks by NAC Chair	General Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council
9:10 am	Public Input	
9:15 am	Science Committee Report	Dr. Meenakshi Wadhwa, Interim Chair
10:00 am	Aeronautics Committee Report	Mr. John Borghese, Chair
10:45 am	Council Discussion and Final Wrap-Up	All
12:00 noon	Adjournment	

# **APPENDIX B**

# NASA ADVISORY COUNCIL MEMBERSHIP

#### NASA Advisory Council Members:

General Lester L. Lyles, Chair Dr. Penina Axelrad Mr. John Borghese Mr. Kenneth Bowersox Dr. William Ballhaus Mr. Tony Cole Dr. Alan H. Epstein, Ex Officio Mr. Michael Gold Mr. N. Wayne Hale Dr. Fiona A. Harrison, Ex Officio Dr. Aimee Kennedy Mr. Miles O'Brien Dr. Elisabeth Paté-Cornell Dr. Patricia Sanders Dr. Meenakshi Wadhwa Ms. P. Diane Rausch, Executive Director

U.S. Air Force (Ret.) University of Colorado, Boulder Rockwell Collins ATC U.S. Navy (Ret.) Aerospace Corporation (Ret.) FireEve Chair, Aeronautics and Space Engineering Board Maxar Technologies Special Aerospace Services and NASA (Ret.) Chair, Space Studies Board Battelle Independent Journalist Stanford University Chair, NASA Aerospace Safety Advisory Panel Arizona State University NASA Headquarters

## APPENDIX C

## **MEETING ATTENDEES**

#### NASA Advisory Council Members:

General Lester L. Lyles, *Chair* Dr. Penina Axelrad Mr. Kenneth Bowersox Mr. Matt Mountain

Dr. Tony Cole Mr. John Borghese Dr. Alan H. Epstein, *Ex Officio* Mr. Michael Gold Mr. N. Wayne Hale Dr. Aimee Kennedy Dr. Elisabeth Paté-Cornell Dr. Patricia Sanders Dr. Meenakshi Wadhwa Ms. P. Diane Rausch, *Executive Director* 

#### NASA Attendees:

Marguerite Broadwell, NASA Headquarters Kris Brown, NASA Headquarters Jason Crusan, NASA Headquarters Elaine Denning, NASA Headquarters Prasun Desai, NASA Headquarters T. Jens Feeley, NASA Headquarters William Gerstenmaier, NASA Headquarters Beverly Girten, NASA Headquarters James Green, NASA Headquarters Hashima Hasan, NASA Headquarters Marcia Joseph, NASA Headquarters Janet Karila, NASA Headquarters Mike Kincaid, NASA Headquarters Marla King, NASA Headquarters Rebecca Lee, NASA Headquarters Nate McIntyre, NASA Headquarters Toni Mumford, NASA Headquarters Michael New, NASA Headquarters Jim Reuter, NASA Headquarters Irma Rodriguez, NASA Headquarters Andrew Rowe, NASA Headquarters Thomas Zurbuchen, NASA Headquarters

#### **Other Attendees:**

Alexia Boggs, Maxar Technologies Ryan Faith, U.S. House of Representatives Lennard Fisk, COSPAR Mary Floyd, Electrosoft, Inc. Grace Hu, Office of Management and Budget G. Swiney, Department of State Joan Zimmermann, Zantech IT U.S. Air Force (Ret.) University of Colorado, Boulder U.S. Navy (Ret.) Association of Universities for Research in Astronomy (sub for Dr. William Ballhaus) FireEye Rockwell-Collins ATC Chair, Aeronautics and Space Engineering Board Maxar Technologies Special Aerospace Services and NASA (Ret.) Battelle Stanford University Chair, NASA Aerospace Safety Advisory Panel Arizona State University NASA Headquarters

#### WebEx Attendees:

Adam Greenstone, NASA Headquarters Adam Thiey, Sierra Nevada Corporation Al Condes, NASA Headquarters Ana Dempling, NASA Headquarters Angela Clark-Williams, Electrosoft Anthony Corlanglio, Main Engine Cutoff Betsy Pugel, NASA Headquarters Bette Siegel, NASA Headquarters Bill Beckman, Boeing Bill Peterson, Self Bret Fullcox, BWXT Carol Warner, NASA Headquarters Chris Moore, NASA Headquarters Christen Kapavik, Coalition for Deep Space Exploration Colleen Hartman, National Academy of Sciences Cynthia Martin-Brandon, International Space Station National Labs Dan Thomas, NASA Dan Troy, Office of Management and Budget Darrell Branscome, NASA Consultant Dave Barrett, NASA Headquarters David Eisenman, NASA Jet Propulsion Laboratory Denise Varga, NASA Headquarters Doug Craig, NASA Headquarters Elaine Denning, NASA Headquarters Elsie Weigel, NASA Eric Berger, Ars Technica Gale Allen, ASGSR Garry Burdick, NASA Jet Propulsion Laboratory Gene Mikulka, Talking Space Grace Hu, Office of Management and Budget Irma Rodriguez, NASA Headquarters Jacob Bleacher, NASA Headquarters James Dean, Florida Today James Lochner, Universities Space Research Association James Miller, NASA Headquarters Jamie Yurechko, Avascent Janes Spry, STI Institute Jeff Hanley, Aerospace Corporation Jidendra Joshi, NASA Headquarters John Guidi, NASA Headquarters John Rummel, SETI Institute Joseph Koller, Aerospace Corporation Josh Barrett, Boeing Juan Santos, NASA Headquarters Julie Ann Arnold, Ball Aerospace Justin Hornback, NASA Headquarters Karen Fisher, NASA Headquarters Karl Becker, NASA Kathy Laurini, NASA Keith Cowing, NASA Watch.com Kelly O'Rourke, NASA Headquarters Kevin Larman, NASA Langley Research Center Kristin Van Wychen Linda Billings, NIA

Linda Karanian, Karanian Aerospace Marcia Smith, Space Policy Online.com Margaret Kieffer, NASA Headquarters Mario Perez, NASA Headquarters Mark Siebert, NASA Contractor Mary Lynne Dittmar, Coalition for Deep Space Exploration Matthew Landess, Attorney Max Grasso, Avascent Mia Brown, National Academy of Sciences Michael Ching, NASA Headquarters Mike Green, NASA Headquarters Miles Doran, CBS News Nicole Herrman, NASA Headquarters Pat Troutman, NASA Headquarters Rebecca Regan, Boeing Richard Rogers, Stellar Solutions Rick Irving, NASA Headquarters Shawn Karcz, NASA Headquarters Stephanie Coangelo, Main Engine Cutoff Stephen Clark, Space Flight Now Steve Carrett, NASA Headquarters Suzanne Gillen, Maxar Technologies Terry Arnold, Boeing Theodore Kronmiller, Law Office Tim Lochner, Universities Space Research Association Unmeel Mehta, NASA Headquarters Valerie Chabot, NASA Headquarters A Pink, Innovative Federal Strategy Alfred Cadrosm, Space Systems Loral Bill Beckman, Boeing Brian Jace, House of Representatives Eric Berger, Ars Technica Isao Kotani, Japan Aerospace Exploration Agency Jeff Foust, Space News Richard Rogers, Stellar Solutions Stephen Clark, Space Flight Now

# **APPENDIX D**

# LIST OF PRESENTATION MATERIAL

- 1) Explore: Extending Human Presence into the Solar System Mr. William Gerstenmaier
- 2) Human Exploration and Operations Committee Report Mr. Kenneth Bowersox
- 3) Technology, Innovation and Engineering Committee Report Dr. William Ballhaus
- 4) Regulatory and Policy Committee Report Mr. Michael Gold
- 5) STEM Engagement Committee Report Dr. Aimee Kennedy
- 6) Science Committee Report Dr. Meenakshi Wadhwa
- 7) Aeronautics Committee Report Mr. John Borghese