

**National Aeronautics and Space Administration
Washington, DC**

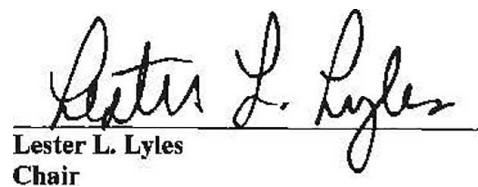
NASA ADVISORY COUNCIL

December 7-8, 2017

**NASA Headquarters
Program Review Center (9H40)
300 E Street SW
Washington, DC**

MEETING MINUTES


P. Diane Rausch
Executive Director


Lester L. Lyles
Chair

NASA ADVISORY COUNCIL

**NASA Headquarters
300 E Street SW
Washington, DC**

**Public Meeting Minutes
December 7-8, 2017**

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*Meeting Report prepared by
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NASA ADVISORY COUNCIL

NASA Headquarters
300 E Street SW
Washington, DC

PUBLIC MEETING

December 7-8, 2017

December 7, 2017

Call to Order, Announcements

Ms. P. Diane Rausch, Executive Director of the NASA Advisory Council (NAC or Council), called the final NAC meeting of 2017 to order, and extended a welcome to Council members and attendees. She provided details that governed the NAC as a Federal advisory committee, established under the Federal Advisory Committee Act (FACA). The meeting is open to the public. 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

Ms. Rausch introduced the NAC Chair, General Lester L. Lyles, who brought the meeting to order, and welcomed two new NAC members: Mr. Tony Cole, a former member of the NAC Institutional Committee, and Mr. John Borghese, the new Chair of the NAC Aeronautics Committee. He reviewed the day's agenda and led introductions around the table, and welcomed Mr. Robert Lightfoot, Acting Administrator of NASA.

Remarks by NASA Acting Administrator

Mr. Lightfoot thanked the incoming NAC members for their upcoming service to NASA, and thanked General Lyles for his support. He reported that NASA was voted the "best place to work" in the Federal Government for the sixth consecutive year. Ms. Krista Paquin was recently named Deputy Associate Administrator upon the retirement of Dr. Lesa Roe at the end of September 2018. The President's nominee for new NASA Administrator, Mr. James Bridenstine, has had a Senate confirmation hearing at the committee level, and the committee subsequently voted to move his confirmation forward. Full confirmation is still to be determined. Mr. Lightfoot noted the recent passing of Richard (Dick) Gordon on November 6, 2017. Dick Gordon was a Gemini and Apollo astronaut and served as the command module pilot for the Apollo 12 mission, the second lunar landing mission. NASA will be operating on a Continuing Resolution (CR) through December 8, 2017, and would likely function under another CR through December 22, 2017. The Congressional appropriations committees are currently talking about budget caps. NASA's 2017 financial report was released on November 15, 2017, with an auditor's unmodified opinion declaring a clean audit. This is seventh consecutive clean audit for NASA, which indicates that a good set of internal controls is in place. Mr. Lightfoot acknowledged his appreciation for the significant role played by the former NAC Audit and Finance Committee, which helped NASA get to the excellent position where it is today. The re-established National Space Council is reviewing a draft on future exploration objectives; NASA is pleased with the level of interest. The Users' Advisory Group will be chartered in the near future represent the views of commercial space entities to the National Space Council; its membership will be finalized over the coming weeks.

Vice President Pence visited the Marshall Space Flight Center (MSFC) in September 2018, and Vice President Pence and Ms. Ivanka Trump participated in this year's Solar Eclipse events, which posed a great opportunity for

NASA to share its ongoing study of the Sun. Vice President Pence also visited Colorado to view the InSight mission before its launch in 2018. Astronauts Peggy Whitson and Mr. Jack Fisher received a special welcome home, marking Dr. Whitson's record-setting time in space. Mr. Lightfoot was present in Russia for the launch of the International Space Station's (ISS) Expedition 52 team. Expedition 53 will launch on December 12, 2017. Mr. Lightfoot noted the increasing usage of robotic arms on ISS. NASA Space Communications support has been recently bolstered by the latest Tracking and Data Relay Satellite (TDRS) launch to orbit.

NASA is kicking off a Science, Technology, Engineering and Mathematics (STEM) activity with ISS, entitled the "Year of Education on Station" (<https://www.nasa.gov/audience/foreducators/stem-on-station/forstudents>), which will involve the participation of teacher astronauts in the coming year. The first Space Launch System (SLS) flight, known as Exploration Mission-1 (EM-1), has been pushed out to a launch date of 2019. A launch of a Cygnus cargo flight to ISS took place on November 12, demonstrating the resilience of the supply chain. Cygnus also released some CubeSats as part of its flight. SpaceX is scheduled to fly to ISS the second week of December 2017, marking the first flight of a re-used first stage, and a re-used Dragon capsule. NASA's Technology program received 19 proposals for Phase 2 grants in the Small Business Technology Transfer (STTR) program, to support technology development in aerospace, human exploration and operations, launch propulsion systems, robotics and autonomous systems, life support, science, materials and manufacturing. NASA awarded a first place prize of \$250K in this year's Centennial Challenge, for completing a phase of a 3D-printed habitat. In Aeronautics, research informing the manufacture of highly flexible and lightweight wings has been making progress. These efforts could be critical to future fuel-efficient planes, quiet flight, and integration of drones into automated air traffic control systems. In Science, NASA has been soliciting proposals in the Explorer program to fill in the gaps between larger science missions. Recent selections have been made; five proposals in Heliophysics, and six in Astrophysics for subjects such as neutron stars, and infrared emissions from galaxies and exoplanets. Exoplanet detection remains of tremendous interest globally.

Mr. Lightfoot provided other NASA highlights since the July 2017 NAC meeting. He described his own educational experience viewing the August 2017 total solar eclipse while flying in a plane over Oregon with Dr. Thomas Zurbuchen, Science Mission Directorate (SMD) Associate Administrator (AA). The Cassini mission to Saturn ended on September 15, 2017, a ground-breaking mission that discovered ocean worlds on Titan and Enceladus, and changed the textbooks. The Light and Gravitational-wave Observatory (LIGO) and Fermi detected a collision of neutron stars in the constellation Hydra, the first simultaneous detection of gamma ray burst and a gravitational wave signal. The Earth Science Division's Grace satellite ended 15 years in orbit; its successor, the Grace Follow-on (Grace-FO), will be launched soon to keep tabs on Earth's water levels. The latest Joint Polar Satellite System (JPSS) satellite launched on a Delta II rocket on November 18, 2017. The Earth Science Division lent its support in searching for a missing Argentinian submarine.

Overall, NASA is making good progress. SLS is going forward, a strong science program continues, and research in aeronautics continues to bring great benefits to the nation's commercial airline industry. Mr. Lightfoot looked forward to 2018, the year NASA celebrates its 60th anniversary. He noted that he had not expected to be serving in the "NASA Acting Administrator" position for this long, and added that it had been an honor and privilege to work with the many motivated teams around the country. General Lyles observed that everyone respects and admires Mr. Lightfoot as a true leader. Regarding NASA as being voted again this year as the "best place to work" in the Federal Government, General Lyles asked whether the NASA mission or the management environment was responsible. Mr. Lightfoot answered that NASA has both characteristics, but he felt the incredible mission was inspiring, and aided by a good set of first-line supervisors. General Lyles asked if NASA was looking more closely at the next SpaceX launch, given its re-use of the first stage. Mr. Lightfoot confirmed that NASA indeed performed an extra flight readiness review, with which SpaceX was very cooperative. He remarked it as another step in refining the integration between government and commercial space. Mr. William Gerstenmaier, AA of the Human Exploration and Operations Mission Directorate (HEOMD), added that the extra review was a "one-off" review, which NASA plans to do until it understand the process thoroughly. General Lyles, noting he had been the original Delta II director, said he would like to be present when the last Delta II launches. Mr. Lightfoot and Mr. Gerstenmaier agreed to keep him apprised.

Aeronautics Committee Report

Mr. John Borghese, new Chair of the Aeronautics Committee, began his report by commending his predecessor, Ms. Marion Blakey, and welcomed the newest member, Dr. Eric Ducharme. He noted the Committee retains its balance of leaders in research and development (R&D) and academia. The Committee met on November 15-16, 2017, to review some new initiatives, tour NASA Ames Research Center (ARC), and view the X-57 and Low Boom Flight Demonstrator (LBFD). The Aeronautics Committee developed three findings and one recommendation. The LBFD is the Aeronautics Research Mission Directorate's (ARMD) first manned X-plane in many years, to address a clear and pent-up need for supersonic flight, particularly in the business population that flies internationally. A market of 350 business jets, and 1500 air transport aircraft has been identified. The Aeronautics Committee believes the U.S. must lead the effort and maintain its superiority in aerospace industry exports, whether by increasing efficiency or by getting faster. Two barriers to supersonic flight are the sonic boom, and efficiency and economic viability. These challenges can now be addressed with modern technology. One goal is to demonstrate that noise from sonic booms can be reduced to a level that is acceptable to the population, currently thought of as a reduction of 60 decibels (dB) relative to conventional boom. The issue is not just sound, but the fact that booms shake buildings and rattle windows. Dr. Alan Epstein commented that a major objective is to generate community feedback. The intensity of the boom is related to how large the aircraft is and how fast it flies. Dr. Ballhaus noted that NASA still has to be concerned about ozone. Mr. Borghese said some ozone concerns are addressed by higher efficiency. Dr. Epstein added that another issue is takeoff noise, as the requirements for commercial aircraft are now more stringent. However, there are no legal requirements for supersonic aircraft for either ozone or noise, so companies are reluctant to invest. The Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO) are starting to look at noise. To comply with ozone regulations, planes fly at lower altitudes. Interestingly, improvements in climate science have shown that the atmosphere's remaining fluorocarbons are actually mitigating NOx concentrations, and may do so for several more decades.

Mr. Borghese reported that work is also being done to better determine where the boom will be distributed on the ground, as some atmospheric conditions do not allow the boom to reach the ground. The three objectives of LBFD are to validate hardware for overflight testing, test the methodology, and acquire community response data. Three criteria of the boom are measured loudness, Mach number, and the number of cruise passes that can be a minimum of 20 minutes apart. The LBFD prototype has a long nose and no windscreen, and is being developed using as much government-furnished equipment (GFE) hardware as possible. An external vision system will replace the windscreen to provide forward vision for the pilot. The X-plane governance being developed by ARMD is based on best practices and on tailored NASA Policy Document (NPD) 7120.5 requirements. An Independent Review Board (IRB), comprised of a distributed team, will report directly to the NASA Administrator. General Lyles thought it would be beneficial for Department of Defense (DoD) representation to be on the IRB. Mr. Borghese reported that there had been some DoD engagement on wing design. The baseline mission rationale will include subsonic climb and cruise at multiple altitudes. No specific community has been chosen yet for feedback. Dr. Epstein commented that in such aircraft, the engine can be a lot larger, but the tradeoff is fuel consumption. He also reminded the Council that the technology is already advanced; military supersonic craft are flying around the world all the time.

The Aeronautics Committee addressed top issues and mitigations staffing in ARMD. Four positions were unfilled at the time of their November 2017 meeting. Budget and reserves were also a concern, and ARMD has scheduled risk workshops on this topic. ARMD has a detailed GFE plan in work, and is working to set expectations with contractor and fund reserves. Asked if the contractors had any flexibility, Mr. Borghese said he understood that contractors must get as close as possible to the NASA design specifications. The configuration is to be locked down in Summer 2018.

Mr. Borghese proposed a finding to the ARMD AA on the Low Boom Flight Demonstrator. Mr. Borghese stated that it was important to engage the public appropriately, and also applauded the single chain of command for the project. Dr. Epstein commented that NASA should regard the demonstrator primarily as a scientific approach and a research tool to determining what levels of noise are acceptable to communities, so that thoughtful legislation and regulation can be developed. Dr. Ballhaus cautioned about having upfront reserves to prevent overruns and subsequent cancellations. General Lyles suggested that NASA think about how the demonstrator data would be transmitted to the appropriate companies. Mr. Borghese reported that NASA is engaged with numerous companies that have interest in building such aircraft. General Lyles noted that there may be a market for transoceanic flight.

Following discussion, the Council approved the following finding on the Low Boom Flight Demonstration project to the ARMD AA:

The Aeronautics Committee expressed excitement and applauds the progress of the Low Boom Flight Demonstration (LBFD) project, and is looking forward to staying abreast on the future steps. The Committee emphasized the importance of community outreach, and provided examples on how to involve students to learn about NASA efforts. The Committee also applauds the single chain of command employed on LBFD as being important to the success of such a large program as well as using the best talents across the NASA Aeronautics Research Mission Directorate (ARMD) locations, but cautioned NASA to take careful consideration as to how the virtual office is set up so that there is a clear understanding of the line of authority. The Committee also applauded outreach from other parts of NASA as well as the risk reduction underway, and suggests that risk reduction projects be funded to the extent necessary since NASA has not developed a manned X-plane recently.

Mr. Borghese proposed a finding to the ARMD AA on the System Wide Safety Assurance Project. Mr. Borghese noted that the current mishap rate is 10^{-7} per flight. The question of whether a real-time system wide safety analysis can detect unsafe conditions and alert operators is still open. Analysis of machine learning and intelligent systems has shown that some events point to a need for more training. A mishap in San Francisco in recent years occurred because the crew ignored an unstable condition until it was too late. The SWS is a 30-year program. The first decade is development, the second is implementation, and the third is automation. SWS can have a tremendous impact and benefit on terminal operations, as 88% of fatal accidents occur in the terminal area. The hardest problem is getting the data on the real incidence of mishaps. Original equipment manufacturers (OEMs), etc. are loath to release this data. Getting universities involved in uncovering this data may be helpful. General Lyles agreed, noting it may be a great opportunity for a “challenge” in the Aeronautics group. Mr. Kenneth Bowersox said that an anonymous reporting database still exists, called the NASA Aviation Safety Reporting System (ASRS). Dr. Aimee Kennedy commented that STEM engagement should not be overlooked as it is in alignment with ARMD.

Following discussion, the Council approved the following finding on System Wide Safety to the ARMD AA:

The Aeronautics Committee finds that the System Wide Safety (SWS) project has progressed well and provides an opportunity to get students excited about engineering. Specifically, the Committee encourages NASA to partner with universities in generating data – data is hard to get and it could be a space that universities can help fill. The Committee cautions NASA to engage with the machine learning community with particular focus on false alarms in the system. The Committee agrees with NASA’s focus on Terminal Area Operations with emphasis on the most critical needs in traditional aviation and Unmanned Aircraft Systems (UAS) Traffic Management (UTM) for near-term needs to support unmanned and autonomous systems. The Committee recognizes that SWS is a big challenge and agrees with the approach to start with a few tasks first to gain an understanding of the effectiveness of the technology. The SWS team should also keep abreast of new algorithms and approaches in this rapidly moving technology area.

Mr. Borghese proposed a finding to the ARMD AA on the Hypersonics Project. General Lyles noted that the intelligence community, as well as the U.S. Air Force, has high interest in hypersonics as a game changing technology; there is good reason to think DoD will run with it. Anything NASA can add would be good leverage. The National Space Council also has an interest in hypersonics (as in Mars atmospheric entry). General Lyles noted that the NAC could pass the message to the NASA Administrator that hypersonics is a national imperative, and that the National Space Council could address Hypersonics writ large. General Lyles asked that this finding be considered separately as a finding to the Administrator, with some extra language to be discussed.

Following discussion, the Council approved the following finding on Hypersonics to the ARMD AA:

The Aeronautics Committee believes that the work that NASA is doing is important in order to maintain U.S. supremacy in Hypersonics by developing tools, technologies and methodologies as well as training the future workforce in this area. The project has a clear focus on the understanding of the fundamental physics of transition for multi-mode hypersonic engines and other key hypersonic phenomena and technologies, and NASA has an opportunity for important technology validation. NASA also has a focus on the important challenge of understanding and validating the quantification of uncertainty, as minor

changes can have a significant impact to vehicle performance. The Committee expressed concern that NASA project personnel have to access to the data collected even in cases where the data is sensitive. The Committee also suggested outreach opportunities with universities in this important area for the U.S..

Mr. Borghese proposed a recommendation to the ARMD AA on autonomy thrust, and addressed the rationale behind this recommendation, which was the consideration of challenges to emerging markets. Eventually, users will request on-demand mobility. Autonomous vehicles are envisioned as a means to provide service to underserved airports; to cost effectively accommodate thousands of times the numbers of vehicles flying today. It will be imperative to ensure that all forms of aviation will be as safe as commercial air transport today. The future civil unmanned airspace environment is evolving, and the U.S. must maintain leadership. U.S. companies are going outside the U.S. to test (for example, in Dubai, Sweden, China). Emerging market opportunities such as urban on-demand mobility; large unmanned aerial vehicles (UAVs) flying above 60,000 feet; noise; vehicle robustness (weather-tolerance); assured autonomous systems and human integration; and air traffic control systems that integrate commercial flights with autonomous flights. ARMD has stood up a Virtual Development and Integration Office (vMDIO) to deal with these challenges; it facilitates a “one ARMD” approach to enable the emergence of safe, practical urban air mobility. To determine where NASA should allocate precious resources, two market studies are underway (Booz Allen, and McKinsey and Co.). The reports are due in twelve and four months, respectively. Essentially, the recommendation is to harmonize the two studies. Dr. Epstein commented that NASA should focus on what is most important; the objective should be based on the proposition of operating an autonomous vehicle in U.S. airspace safely. This should direct NASA as to how it spends its resources. NASA certainly is also the most qualified agency to do this as well. The FAA and commercial entities cannot do a job equivalent to NASA. Dr. Cole commented that cybersecurity implications are also critical, given the potential for jamming Global Positioning System (GPS) signals, hacking, and taking over a vehicle in motion. General Lyles asked Mr. Borghese to reword the recommendation slightly, adding issues and gaps.

Following discussion, the Council approved the following recommendation on autonomy thrust to the ARMD AA:

The Aeronautics Committee agrees that the NASA research in autonomous vehicles and autonomy is important for the U.S.. Because of new technology, market demand and industry investment, autonomy and autonomous vehicles could change aviation similar in scope to the birth of aviation. Because of these dynamics, the Committee agrees with the approach to have independent evaluations of the autonomous vehicle market. The Committee recommends that NASA harmonizes the two studies so that the results are presented contemporaneously to receive more value. The Committee also recommends that the NASA Aeronautics Research Mission Directorate (ARMD) identify issues and gaps that need to be addressed regardless of the studies' outcomes.

Mr. Borghese closed with a brief discussion of the Aeronautics Committee work plan and upcoming topics.

Technology, Innovation and Engineering Committee Report

Mr. Bill Ballhaus, Chair of the Technology, Innovation and Engineering Committee, began his briefing with a definition of technology as a solution that arises from applying the disciplines of engineering science to synthesize a device, process, or subsystem to enable a specific capability. NASA used to fund a lot of systems engineering to synthesize things that can be used for NASA. The Technology, Innovation and Engineering Committee met on December 5, 2018, and discussed two new space technology research teams that have been set up at the NASA Langley Research Center, and the NASA Ames Research Center.

Dr. Ballhaus referenced a prior July 2016 Committee recommendation to the Space Technology Mission Directorate (STMD) to commission an Institute for Defense Analyses (IDA) study on a discriminating role for NASA and STMD in small satellites, or CubeSats (up to 200 pounds). Recommendations from the study were received in the Spring; the main thrust of the study was that IDA felt NASA had not effectively communicated its unique role in small satellite technology. Dr. Ballhaus introduced a current finding stemming from the study outcome.

Following discussion, the Council approved the following finding on Small Satellite Technology to the STMD AA:

The NASA Space Technology Mission Directorate (STMD) should be commended for following through to implement the recommendations from the Institute for Defense Analyses Small Satellite study, focusing investments on relevant NASA mission areas and pre-competitive platform technologies. The Technology, Innovation and Engineering Committee is satisfied that STMD has met the intent of its July 2016 recommendation. In executing this plan, there appears to be a bottleneck in acquiring launch opportunities. The Committee is requesting more information to understand the impact and potential means to reduce this delay.

Dr. Ballhaus reported that STMD is testing a fission-based space power source, the Kilopower Project, in March 2018, and displayed a video of the engine module. The nuclear-powered Stirling engine, called KRUSTy (Kilowatt Reactor Using Stirling Technology), has met its major development milestones. One item that will require close attention and follow-up is waste disposal.

Dr. Ballhaus reported that his Committee held an extensive discussion about Engineering Research and Analysis (R&A) investment at NASA, which he noted had been declining for two decades. NASA had tried to respond to a 2013 NAC recommendation on this subject, but basically NASA is still “bootlegging” general engineering R&A across the Agency, and not in a strategic manner. NASA has agreed to create a coordination board, comprised of senior executives watching and coordinating engineering research, and providing visibility at a high level in part to address the strategic thrust. The Committee is hopeful that this approach will work. Mr. Steve Jurczyk, STMD AA, said he agreed with the recommended approach. Dr. Epstein suggested a 1% tax on everything at NASA to fund engineering research, keeping the funds aligned with missions, Both Mr. Hale and Dr. Ballhaus rejected this idea, citing their experience as former program managers, as yet another tax on the programs. General Lyles noted that the ARMD AA, Dr. Jaiwon Shin, had been successful in getting a foundational line in Aeronautics, which eventually earned Congressional support. Dr. Ballhaus did not think a similar was necessary for STMD, but thought NASA could do a better job in communicating outcomes. He said that in the past, NASA had funded engineering R&A through a base account, and as a result, basic and applied research was greatly reduced. Former NASA Administrator Charles Bolden had tried to reverse this by standing up STMD. NASA needs to fund an engineering “stable” that does not need to compete for funds. The Committee believes that NASA’s current plans for funding Engineering R&A this year is a good start, but has potential issues.

The Committee discussed a revision of STMD’s strategic framework to begin a focus on impact and outcome to customers, to be considered as mega-drivers to strategic thrusts such as the expansion and utilization of space. Give the current STMD funding for FY 2017, Dr. Ballhaus felt the framework is a good construct, and is maturing well. General Lyles suggested that DoD would add resiliency to the list of mega-drivers, as threat is what drives the concept of resiliency; NASA needs to be aware of it.

The Committee reviewed activities at the NASA Langley Research Center’s Space Technology Research Institute, which has a focus on manufacturing for ultra-high strength lightweight structures. This is an idea whose time has come. The institute also ties together a number of universities, and has specific requirements and end products. Proving concepts is the scope of effort, and does not include certification at present. In the next few years, NASA will start looking at other centers to build on the technology that comes out of this activity. Manufacturability is part of the effort; NASA has worked with one company for a decade to create the carbon nanotubes being used. General Lyles asked if the institute was considering biomimetic technologies. Mr. Jurczyk answered yes, and in particular cited 3-D printing methods as having proved a boon to their development. General Lyles advised STMD to contact the Air Force Research Laboratory (AFRL) and touch base.

NASA Ames Research Center is hosting an institute for Biomanufacturing for Deep Space Exploration, which is working on *in-situ* microbial production, with the University of California at Berkeley as lead, and which includes Stanford University as well. Technologies in use including a powerful DNA editing method called CRISPR, which has wide implications. General Lyles suggested that NASA seek out historically minority institutions, and add it as a requirement to be a forcing function. Mr. Jurczyk agreed.

Dr. Ballhaus presented language to be added to a Science Committee finding on the esteemed NASA civil servant workforce, which was approved by the Council:

The Council would also like to emphasize the value of NASA civil service technologists and researchers that invent, acquire, and adapt advanced technologies and capabilities (e.g., engineering methods) to the needs of NASA's science and exploration projects.

[Note: This topic became a joint finding of NAC Science Committee and the NAC Technology, Innovation and Engineering Committee. See the Science Committee Report for the complete text that was approved by the Council.]

Ad Hoc Task Force on STEM Education

Dr. Aimee Kennedy, Chair of the Ad Hoc Task Force on STEM Education, reviewed the present composition of the Task Force, which is down to five members, and which will need to be enlarged as the transition continues. The Task Force has shifted to a focus on partnerships and moving forward under the Office of Education's Acting Associate Administrator, Mr. Michael Kincaid.

Dr. Kennedy introduced one, multipart finding. Following discussion, the Council approved the following finding, and recommended that it be subdivided into 6 separate findings.

Business Services Assessment (BSA)

The Council's STEM Task Force has had a chance to look at more of the Business Services Assessment (BSA) details for the Office of Education, and the Council concurs that the BSA efforts are addressing the issues that have been previously highlighted. The Council believes that the initial results have the potential to help NASA move forward in a more strategic and focused direction.

Measurement and Evaluation

The Office of Education is revamping the current plan to improve performance measurement and evaluation of NASA's STEM engagement activities. This effort has been briefed to the Office of Management and Budget (OMB), the National Science Foundation (NSF), and the NASA Advisory Council's STEM Task Force. The Council is encouraged by the collaboration, and support the further development and implementation of this plan.

Functional Leadership

Building on the efforts of the Business Services Assessment (BSA), the NASA Office of Education is working across organizations to facilitate an integrated STEM education strategy that includes NASA Headquarters Mission Directorates and Staff Offices, as well as NASA Centers.

STEM Engagement

NASA plays an essential role in STEM engagement across the U.S.. The aspirational change desired from this effort is complex. To sustain long term success of this effort, collaboration and commitment will need to be guaranteed across the Agency.

Broadening Participation

NASA's commitment to reaching underrepresented and underserved communities has been a long-term priority throughout the history of its STEM engagement activities. NASA should be sure to not lose sight of the role it has played, and should continue to play, in engaging, educating, inspiring, and employing underserved populations in the STEM workforce.

Mr. Borghese asked if the Task Force had identified metrics on successful outcomes of STEM education. Dr. Kennedy described metrics as nascent, and noted that Mr. Kincaid had dealt with this question with the Office of Management and Budget (OMB). The Task Force is trying to find best practices, and is creating an advisory panel on evaluation, and is also doing a literature review. Metrics have largely been left to individual grantees. By the end of FY 2018, there will be a plan in place to make a more holistic evaluation. General Lyles noted that Dr. Kennedy's employer, Battelle Corporation, has a good number of statistics associated with best practices that NASA could take advantage of.

Dr. Kennedy closed with a recommendation on elevating the NAC Ad Hoc Task Force on STEM Education, noting that it had been presented to the NAC at a previous meeting:

The NASA Advisory Council Ad-Hoc Task Force on STEM Education should become a regular committee of the NAC.

Dr. Kennedy noted that the STEM Task Force was due to dissolve in November 2018. Mr. Cole thought the STEM pipeline was not yet where it should be. General Lyles agreed to take this discussion to the NASA Acting Administrator to turn this into a full committee. Mr. Bowersox commented that the decision is really up to the next NASA Administrator and could be handled off-line, rather than a formal recommendation from the Council. General Lyles agreed.

Council Discussion

General Lyles asked if NAC members had any specific items to bring up. Mr. Hale offered, as a general comment, that a lot of great work is going on, but that NASA needs to match resources to missions assigned to the Agency; NASA gets in trouble when this does not happen. The NAC should help to remind the Agency that they do not need to take on things that they do not have the resources for. General Lyles concurred that this is the number one concern of the whole NAC. He added that the National Space Council is anxious to hear these concerns, and that he hoped to use the auspices of the National Space Council to get this topic placed before the new NASA Administrator. He was interested in hearing from other NAC members on what they would like to deliver in the future. Technically, the NAC is much smaller than it once was. Is it time to enlarge it? Mr. Bowersox suggested presenting the new NASA Administrator a graphic representation of the structure of the NAC under the different Administrators. Ms. Rausch could provide such a graphic representation at the appropriate time.

December 8, 2017

Introduction

Ms. Rausch opened the session and made several administrative announcements, then turned the meeting over to General Lyles.

Opening Remarks

General Lyles asked members to re-introduce themselves around the table.

Public Input

Dr. John Rummel commented that as NASA continues to search for life in the Solar System, a specific responsibility codified in the Space Act, he hoped the Agency would deal responsibly with avoiding contamination of the Solar System's biosphere by reinstating the former NAC Planetary Protection Subcommittee as an essential element, whether placing it under the NAC Science Committee (as in the past) or as a stand-alone committee. He offered to provide any helpful background information. General Lyles thanked Dr. Rummel for his comments.

Mr. Keith Cowing echoed Dr. Rummel's comments, and suggested that similarly, the former NAC Education and Outreach Committee be re-established as an important asset to the Agency. Dr. Lyles commented that he did not believe the NAC was neglecting Education, but would address the comment with the new NASA Administrator.

NASA Exploration Update

Mr. William Gerstenmaier presented an update on NASA's Human Exploration and Operations Mission Directorate (HEOMD), which is continuing to lead space exploration by maximizing the use of the ISS as the first key piece of exploration, where hardware, technologies and operational procedures can be tested. ISS also enhances the progress of commercial activity via accommodating private companies in low Earth orbit (LEO), and by serving as a good

test-bed for the science community. NASA and ISS are actively promoting LEO commercialization, resolving human health challenges, expanding partnerships with industry, growing international partnerships, building critical deep space infrastructure (Orion, etc.), and enabling the ability of humans to explore multiple destinations, starting with the Moon. Mr. Gerstenmaier viewed NASA as leading the movement of humans into Deep Space by influencing, connecting and “orchestrating” industry, missions, science, and international partners as progress moves forward. General Lyles asked about the contributions of new players, e.g., new aerospace companies such as Blue Origin. Mr. Gerstenmaier indicated HEOMD was working with them, and with Sierra Nevada Corporation for cargo activities. NASA recently did a drop test with Sierra Nevada in concert with crewed mission formulation activities. The Agency is also branching and reaching out, working with small companies like Nanoracks. HEOMD continues to maintain the strategic principles of exploration: fiscal realism; scientific exploration; technology push and pull; gradual build-up of capability; economic opportunities; architecture openness and resilience; global collaboration and leadership; and continuity of human space flight. It is important for NASA to establish a regular cadence of crewed missions, and to avoid major disruptions. HEOMD is currently considering acquiring a spacecraft bus from a private satellite company to see if the Agency can create a win-win economic opportunity, producing hardware NASA can use, and giving a small company entry into a major marketplace. General Lyles commented that he loved seeing resilient architecture, given the importance of space resiliency in current threat environment.

HEOMD is also seeking the benefits of public-private partnerships through sharing knowledge, which allows companies to gain experience with NASA’s unique capabilities, provides valuable infrastructure and assets to emerging space companies, and provides early demand as an anchored customer. This approach can lead to new markets and services, which NASA can later acquire, and help lower launch costs for the science community. ISS has helped this approach move forward by developing and implementing cutting edge research.

The Global Exploration Roadmap, which is made up of 14 space agencies participating in a nonbinding agreement, provides a framework for space activities, and will be updated in January 2018. NASA is actively establishing interoperability standards for habitation technologies, docking mechanisms, communications, and thermal system interfaces, among others. The standards are already being seen in use with commercial systems that interact with ISS. HEOMD has put out a Broad Area Announcement (BAA) out in critical areas. There will be a meeting of the International Space Exploration Forum in Japan in March 2018, where NASA will provide these voluntary standards for review. NASA is the keeper of these voluntary standards at present. Mr. Gerstenmaier felt that thus far, NASA’s partners see the benefit of having the standards; they function as a huge motivation for cooperation.

ISS is the first step in deep space exploration and for developing deep space habitation systems that include life support, environmental monitoring, crew health, extravehicular activity (EVA), and carbon dioxide and water recovery. Four ISS racks have been designated for life support; they are in the budget, but not at ideal levels. Radiation protection, fire safety, logistics, and cross-cutting systems in robotics and communications must be further developed and refined. Dr. Ballhaus asked if HEOMD was making technology investments for reducing the supply chain. Mr. Gerstenmaier said that investments in 3-D printing were showing promise, particularly for radiation shield performance monitoring. There are also 3-D print designs of urine collection modules. Technologies to ensure sterilization of biologicals when going from one application to another are also in work. All these technologies are also useful on Earth. ISS is looking at biological systems (e.g., plant walls) as an augmentation to in situ resource utilization, and optimized medical kits, the details of the latter have been shared with the military. General Lyles took an action to open a dialogue with AFRL on this item.

HEOMD is also considering the re-use of ISS elements, as many of them will have structural life after 2028, and has been in discussion with the National Laboratories to ascertain their interest. Some systems will need to be replaced by the end of the 2020s. NASA is currently assessing its LEO long-term requirements. Transition indicators for ISS end-of-life include, affordability, foreign policy, and the timing of non-governmental entities. The NAC Human Exploration and Operations Committee has been engaged in this discussion with HEOMD. China will have a space station by 2022, which will not be as large as ISS. They will start launching elements soon. The orbital inclination is on order of 30 to 40 degrees, compatible with their launch sites. Another consideration is potential hand-off to private partnerships. ISS is keeping the U.S. at the forefront of human space flight and must not be viewed as a liability.

A December 2019 launch date has been set for the first flight of the uncrewed launch vehicle, Exploration Mission-1 (EM-1). Orion just completed avionics testing, and its heat shield is almost complete. The external tank for the

Space Launch System (SLS) is complete, although much work is left on the engine. The hydrogen tank will be tested all the way to failure; this is a test that is hugely important to the industry, and is the right role for the government. The test will help other companies as they come on-line for launch services. Dr. Sanders commented that it is very much worth seeing the amazing scale of the SLS production effort. Dr. Ballhaus asked if HEOMD had seen any composite test failures. Mr. Gerstenmaier recounted that one engine section test showed two cracks that appeared where models had predicted them to appear. He agreed that the magnitude of the test facility is unprecedented, and that the models are maturing rapidly. Dr. Ballhaus commented that added margin makes gross lift-off weight increase exponentially; launch is hard, and is not like aircraft building. Dr. Axelrad asked if HEOMD gets reports on commercial failures. Mr. Gerstenmaier answered that while there are some restrictions on intellectual property, generally they do. NASA's position shows the advantage of government development. HEOMD also contributes to the Aerospace database on failures and anomalies.

NASA is moving out on the power and propulsion element for the Deep Space Gateway (DSG) to ensure flexibility on orbital attitudes. The intent is to use the DSG for multiple decades, for multiple users, around the Moon. Requirements for what the human rating means in terms of the Deep Space concept will have to be re-visited, to allow Orion to come home in normal manner or in an expedited manner when anomalies occur. NASA may look at relaxing the human rating as it learns from communication satellite demonstration activities. Dr. Ballhaus asked how sensitive NASA is to the existence of just a few players in commercial space. Mr. Gerstenmaier described NASA's mitigation strategy, which is based on using parallel users; this is why two providers were chosen for launching cargo. NASA is using the same strategy for crew, paying a slight penalty, but meeting the need through 2024. HEOMD is also diversifying market growth on ISS, and has been reaching out to Big Pharma. For the first time, pharmaceutical companies are using their own funds to fund testing on ISS (e.g., a bone densitometer for rats). General Lyles praised Mr. Gerstenmaier's leadership.

Human Exploration and Operations Committee

Mr. Bowersox gave a status of the Human Exploration and Operations Committee, which met in November 2017 at NASA Kennedy Space Center, where Committee members viewed much hardware. ISS has hosted crews for 17 years; Increments 53 and 54 are currently underway. The program is seeing many more science activities. General Lyles asked if the Russians were doing experiments in U.S. facilities and vice versa. Mr. Bowersox said there has been some limited overlap between crew science activities. At present, a phase-change heat exchanger is being tested on ISS for use on Orion, as Orion's radiators will not be sufficient for heat rejection. Other exploration technology development is also in progress for life support. Many briefings are on commercial crew progress are sensitive, thus the Human Exploration and Operations Committee occasionally sends representatives to the Aviation Safety Advisory Panel (ASAP) for its deep-dive insight meetings. Mr. Bowersox felt the planned dates for eight Commercial Crew Program (CCP) flights was very aggressive. EM-1 has been in the news lately, due to the change in schedules for a number of reasons. A European Space Agency (ESA) module has had an issue with a valve in the critical path, which could be prove to be a problem across the space community. Core stage development was adversely affected by inclement weather at NASA's Michoud facility, as well as by first-time issues. For ground systems, software is the driver; NASA has found that hiring enough engineers to do the work is a problem. While the launch window for EM-1 is now December 2019, some further delays are likely. There is NASA Administrator-level attention to getting all the elements together, and everyone is working hard to improve decision velocity inside the program. Dr. Sanders said she was impressed by the way teams are paying attention to details on a day-to-day basis, regardless of schedule pressure. Mr. Borghese asked what the software issue was; development or certification. Mr. Bowersox said that writing code and getting coders is the issue. Mr. Hale noted that in his experience, ground software often proved to be the limiting factor. Dr. Sanders added that software is also exacerbated by a changes in contractors. Mr. Gerstenmaier said the software updates also come from different elements and providers, but he felt the problem had been identified early enough to work on effectively.

Advanced Exploration Systems (AES) is using the NextSTEP model to make progress in public-private partnerships. An in-situ resource utilization (ISRU) instrument that is being developed for the Mars 2020 rover, Mars Oxygen ISRU Experiment (MOXIE), has been having hardware issues but is moving forward. Payloads are being developed for EM-1, some of which are aimed at learning more about the Moon. In 2014, NASA competitively selected U.S. private-sector partners in a program called Lunar Cargo Transportation and Landing by Soft Touchdown (LunarCATALYST), in an effort to find commercially-viable lunar surface cargo transportation capability. These agreements were renewed in 2017 for two more years.

Mr. Bowersox briefly reviewed strategic principles of human exploration, the key points of which are working with commercial, international, and multi-use elements. The framework of moving from ISS to beyond has been useful. The Committee recommended that if NASA backed away from the Asteroid Redirect Mission (ARM), it should at least continue developing solar-electric propulsion (SEP) technologies to support habitation capabilities in cis-lunar space, and enable DSG to allow a human crew experience in an area closer to Earth before a deep journey to Mars. DSG can provide a safe haven for crew, and storage for landers. There is also the potential for servicing space telescopes and developing commercial capabilities for cargo. The international community seems interested in science at the Gateway. DSG is envisioned as a propulsion test-bed vehicle as well, capable of moving to different orbits such as Lagrange Point 2 (L2) Halo and distant retrograde orbit (DRO). Mr. Borghese asked about the human rating issue: How does this mesh with year-long missions? Does Orion join up with DSG? Mr. Bowersox said these issues are to be decided. One scenario could have Orion docked at DSG, or have landers stored on DSG between launches of Orion. Mr. Gerstenmaier added that whenever crew is present, Orion is present, and that currently, HEOMD is envisioning 30- to 60-day sorties. He added that any lunar lander must also be human-rated.

Mr. Bowersox noted that SEP is essential to the mobility of DSG. Contracts have been awarded to five contractors for the power-propulsion element (PPE). The ISS transition is also key here, as NASA spends about \$3.5B a year in supporting it. The primary cost driver for ISS is transportation. There is some private interest in operating a reduced version of ISS; others want to build their own station. Private interest in LEO must be better understood. NASA needs to help the private sector understand what is available. The National Space Council has already received some actions to work with the Department of Commerce (DOC) on the matter. There is also big commercial interest in giving internationalists their first rides to space. NASA might consider it is in our national interest to do this.

Mr. Bowersox introduced one informal Committee observation on the DSG approach to human rating, noting that his Committee believes it would be helpful for NASA to document how to human-rate human-tended spacecraft.

Mr. Bowersox presented a finding and recommendation for the NAC to consider. Following discussion, the Council approved the following finding:

NASA's current phased approach to exploration which includes the International Space Station (ISS) for the "Earth dependent" phase, Cislunar space for the "proving ground" phase, and goals beyond Cislunar for the "Earth independent" phase, provide a useful framework for future exploration efforts. An important element in the phased approach is that human exploration efforts in the Cislunar "proving ground" contribute to future exploration efforts beyond Cislunar space, even if the focus of Cislunar activity shifts to the lunar surface.

Following discussion, the Council approved the following recommendation:

The Council recommends that NASA work with the National Space Council staff to establish an interactive link between the NASA Advisory Council and the National Space Council.

General Lyles felt it would be helpful to formalize this as a NAC recommendation, based on his experience with the National Space Council. There was general concurrence with the idea.

Mr. Bowersox presented one new Committee concern that shifting priorities may result in the reduction of government funding for the ISS before a viable U.S. commercial follow-on capability is established. General Lyles said that the National Space Council is concerned about this as well, and that he would work with NASA Acting Administrator Lightfoot to transmit this concern to the National Space Council. Mr. Bauhaus, addressing the Committee's perennial bureaucratic process concern, asked Mr. Gerstenmaier for his opinion on this one. Mr. Gerst said he would like to have a further discussion with the NAC in the future, so that key NASA processes and reviews should not be discarded; there needs to be thoughtful reflection on which processes are duplicative and which are not. Mr. Hale commented noted that NASA is celebrating 17 continuous years in space with the ISS, and as we look forward, we want to make U.S. leadership as a continuous presence in space a reality for the future. He support the Committee finding with this comment for the record. General Lyles stated that the NAC may want to give the finding a stronger emphasis. Mr. Bowersox noted that the intent of Committee finding is to "end-run the Moon-Mars paralysis."

Science Committee Report

Dr. Bradley Peterson gave a briefing on the status of the Science Committee, which is maintaining a good range of expertise with the addition of three new members. He presented science results, beginning with a NASA's Solar and Heliospheric Observatory (SOHO) image of the sun with a coronagraph in place, noting that the inner corona is obscured by the coronagraph. The August 2017 total solar "eclipse across America" provided an opportunity to visualize the inner k-corona, image data from which is still being processed. The Moon also functioned as a natural starshade during the eclipse, allowing a look at faint planets and stars. NASA's Earth Science assets were able to provide extensive information about the three major hurricanes of 2017, including Global Precipitation Measurement (GPM) assessments of Hurricane Irma, and Suomi-National Polar-orbiting Partnership (NPP) images of electrical outages in Puerto Rico after Hurricane Maria. A discovery of an interstellar object was made in October 2017 by the PanSTARRS telescope; it originated outside of the Solar System and seems to be a highly elongated asteroid with a 10:1 aspect ratio, representing an extreme end of the shape distribution. It is in a highly inclined orbit, and on its way out. In Astrophysics, the discovery of year was made by the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Fermi, as they detected the collision of two neutron stars, marking the first time short gamma ray bursts and gravity waves were detected at the same time. An interesting feature of such collisions is that they produce the higher atomic weight elements, such as gold and iron, unlike black hole emissions. The Hubble Space Telescope (HST) took an image of a gravitationally lensed, very distant galaxy; researchers were able to reconstruct what the original galaxy looked like, showing individual bands of star formation that corresponds to events in the early universe (2.5B years). Chandra results supported the construction of a 3-D model of a nova, or a collapsed white star, which shows details about the outflow of gas, blast wave, and ejected material.

At their recent meeting, the Science Committee heard a briefing on the Joint Polar Satellite System-1 (JPSS-1), launched in November 2017, which now has a new name, National Oceanic and Atmospheric Administration-20 (NOAA-20). The Committee also heard about significant new capabilities in CubeSats and small satellites, which are providing relatively low launch costs for new capabilities in science. There is high interest in this new class of satellites.

The next major Astrophysics mission after the James Webb Space Telescope (JWST) is the Wide-Field Infrared Survey Telescope (WFIRST), which recently underwent a technical review, the WFIRST Independent External Technical/Cost/Management Review (WIETR). Noting that he was conflicted institutionally, Dr. Peterson offered some facts on the WIETR results, which had found that the Decadal Survey had forced some science, and that donated assets had shifted the wavelength and altered the size of the telescope, in contrast to that which had been envisioned by the Survey. In addition, the mission was developed as a class B, whereas it should have been class A. The mission was also cost capped at \$3.2B at the beginning of phase A, all of which added up to strain on the mission. The WIETR advised that the telescope should be designed for \$3.2B, and that the coronagraph be being treated as a technology demonstration, although it is an important part of the science going forward. Asked if he had insight into the hardware, Dr. Zurbuchen, NASA Science Mission Directorate (SMD) AA, had indicated that the assets were not quite what was expected, and that the telescope surfaces had been exposed to the atmosphere, some factors contributing to cost growth.

In Heliophysics, the Solar Probe Plus mission was renamed the Parker Solar Probe, in honor of Dr. Eugene Parker; this is the first time a spacecraft has been named after a living scientist. At perihelion, the probe will be at 10 solar radii. SC also heard about how Earth Science contributes to society through its Applied Science program, ranging from visualizing electrical outages and developing soil moisture maps. In Nepal, the use of NASA Earth Science data were able to prevent glacial lake outbursts, potentially saving the lives of 100,000 people. In this instance, Kathmandu engineers lowered water levels by 3.5 meters in a threatened lake, greatly reducing the risk of an outburst. Global imaging is being routinely used for fire detection and emergency-response decision-making, on a time scale of tens of minutes to hours. Dr. Zurbuchen noted that while NASA is not the operator (NOAA is), it does develop the products that are sent out to assist decision-makers. Earth monitoring of soil moisture content is also being used to provide early warning of malaria and meningitis outbreaks.

The Planetary Science Discovery program is very active, and includes some deep space small satellites, which can be used in novel ways. Mars 2020 will carry two CubeSats that will be released as the lander enters the Mars atmosphere, to monitor Entry, Descent and Landing (EDL) conditions. The Planetary Defense Office has found one-

third of the 140+ meter Near-Earth Objects it has been assigned to monitor. JWST has just completed thermal vacuum testing, and its sunshield is on its second deployment (folding) test. The launch has been shifted from 6 to 9 months; one factor in the delay parallel testing, and another is a major launch conflict with ESA's BepiColombo mission. There is no extra cost associated with the delay. Dr. Zurbuchen noted that JWST's extended testing came out clean, which was a huge deal. JWST will take six months to reach L2, and also must cool very slowly. Dr. Peterson noted that the sunshield will be deployed immediately. Dr. Zurbuchen added that NASA would have moved the launch regardless of the conflict with BepiColombo, and he offered his kudos to NASA Johnson Space Center on their accommodation of JWST. He had been very impressed with the state of their preparation.

The NAC Ad Hoc Task Force on Big Data (BDTF) has concluded its work and delivered four white papers and concomitant findings and recommendations to the Science Committee. It will take some time to for all the discipline committees to weigh in, and the Science Committee expects to issue findings and recommendations at the next NAC meeting. Big Data is an important issue. Researchers are making heavy use of the NASA archives; the number of papers resulting from archived data now amounts to about 50% of publication output. The Earth Science Advisory Committee (ESAC) completed its 2017 Senior Review and recommended that all operating missions continue. The Science Committee is also reviewing SMD's Research and Analysis (R&A) program practices in terms of identifying high-risk, high-payoff selections. The Astrophysics Advisory Committee (APAC) has made some progress on this issue, and the other committees are looking at their respective divisions to determine whether processes are in place.

Dr. Peterson proposed a joint finding by the Science Committee and the Technology, Innovation and Engineering Committee on the esteemed NASA civil servant workforce. Following discussion, the Council approved the following joint finding:

The Council wishes to acknowledge the science and engineering community's great esteem for its civil servant colleagues. NASA civil servants have worked tirelessly in many roles – as project scientists, mission planners, analysts, archivists, project managers, engineers, and more – to enable the breakthrough science of NASA's missions. The Council would also like to emphasize the value of NASA civil service technologists and researchers that invent, acquire, and adapt advanced technologies and capabilities (e.g., engineering methods) to the needs of NASA's science and exploration projects. The commitment, professionalism, and dedication of NASA's civil servants have earned the respect and gratitude of the science and engineering community. The community considers its civil servant colleagues – along with the missions they support – a national treasure.

General Lyles asked Dr. Peterson to comment on the value of the five new stand-alone NASA science advisory committees (former NAC science subcommittees). Dr. Peterson felt that the new structure is very effective, and was glad that the disciplines were talking to each other. He further noted that there would be a workshop on science enabled by the DSG in February 2018.

Council Discussion

The NAC wrapped up the meeting discussion, reviewing the importance of hypersonics to human exploration, Mars entry, descent and landing (EDL), national security, and its value to the national economy and its recommendation to the National Space Council to view hypersonics in a broad sense. Dr. Epstein commented that when people think about NASA, they think about stellar accomplishments. He noted that the engineering science and technology developed at NASA – computer codes, theory, simulation – each have an impact, but the enormous impact is the sum of the influence on the U.S. economy; this fact is underappreciated. Dr. Cole felt the August 2017 solar “eclipse across America” activities reflected on how well NASA has engaged society, and shows its great benefit to humanity around the globe. Dr. Peterson reflected that in the 6th Century, a solar eclipse briefly stopped a battle between the Persians and Medes. Dr. Ballhaus noted that the continuing difficulty is communicating the importance of NASA work. General Lyles agreed that it was important to keep working on the issue.

Dr. Axelrad felt it would be good to have other advisory groups create ties to the National Space Council. Her other concern was the flow of products from NASA and their transition to NOAA or the private sector; it would be good to know how these things get transitioned, and how they create jobs. General Lyles took an action to transmit this concern, and to perhaps schedule a briefing. Mr. Borghese noted that ARMD does track this to a degree. General

Lyles, referring to Earth Science imagery of moisture in the Houston area, thought that instead of hiring airplanes to overfly fires, there may be ways to use satellite sensing. Mr. Hale asked Ms. Rausch for a link to the ISS transition report when it becomes available.

Council Final Wrap-Up and Acknowledgments

Dr. Cole said he would like to look at cybersecurity challenges in NASA, focusing on commercial relationships and how NASA is controlling this risk to NASA missions. Dr. Elisabeth Pate-Cornell echoed Dr. Cole's words, with an emphasis on software development. Dr. Peterson noted that the interface with the new Administration and the National Space Council is working well now and that he hoped it remained stable. Mr. Bowersox professed enjoying having the NAC meet during a very dynamic time at NASA. Mr. Hale commented that he always felt fortunate to be part of NAC, and seeing all the breathtaking things NASA does to advance humanity. Mr. Borghese said he was amazed at the breadth and depth of NASA and its importance to the U.S..

Dr. Ballhaus commented that as the Technology, Innovation and Engineering Committee looks at the launch bottleneck in small satellites, the Science Committee and the Human Exploration and Operations Committee might also want to be involved. He also expressed gratitude to Mr. Mike Green in pulling together all the slides for his presentation. The Council tentatively scheduled the 2018 meeting schedule: the week of March 19 at NASA Headquarters; the week of July 16 for the summer "annual all hands meeting" at NASA Ames Research Center; and the week of November 26 at NASA Kennedy Space Center. General Lyles thanked the Council members for their dedication to and support for NASA. He adjourned the meeting at 12:03 pm.

APPENDIX A

AGENDA

NASA ADVISORY COUNCIL

**NASA Headquarters
Program Review Center, Room 9H40
300 E Street, SW
Washington, DC 20546**

December 7-8, 2017

PUBLIC MEETING

Thursday, December 7, 2017

1:00 pm	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
1:05 pm	Welcome and Introductions	General Lester Lyles, (USAF, Ret.) Chair, NASA Advisory Council
1:20 pm	Remarks by NASA Administrator (Acting)	Mr. Robert M. Lightfoot, Jr. NASA Administrator (Acting)
2:20 pm	Break	
2:30 pm	Aeronautics Committee Report	Mr. John Borghese Chair, Aeronautics Committee
3:15 pm	Technology, Innovation and Engineering Committee Report	Dr. William Ballhaus Chair, Technology, Innovation and Engineering Committee
4:00 pm	Ad Hoc Task Force on STEM Education	Dr. Aimee Kennedy Chair, Ad Hoc Task Force on STEM Education
4:30 pm	Council Discussion	All
5:00 pm	Adjourn	

Friday, December 8, 2017

9:00 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
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9:02 am	Opening Remarks by NAC Chair	General Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council
9:10 am	Public Input	
9:15 am	NASA Exploration Update	Mr. William Gerstenmaier Associate Administrator Human Exploration and Operations Mission Directorate NASA
10:00 am	Human Exploration and Operations Committee Report	Mr. Kenneth Bowersox Chair, Human Exploration and Operations Committee
10:45 am	Science Committee Report	Dr. Bradley Peterson Chair, Science Committee
11:30 am	Council Discussion and Final Wrap-Up	All
12:00 noon	Adjourn	

APPENDIX B

COUNCIL MEMBERSHIP
NASA ADVISORY COUNCIL

December 2017

Position	Council Members
Chair – NASA Advisory Council	General Lester L. Lyles, USAF (Ret.)
Chair – Aeronautics Committee	Mr. John Borghese, Vice President, Rockwell Collins Advanced Technology Center
Chair – Human Exploration and Operations Committee	Mr. Kenneth Bowersox, U.S. Naval Aviator (Ret.); Former NASA Astronaut
Chair – Science Committee	Dr. Bradley Peterson, Professor Emeritus, Former Chair, Department of Astronomy, Ohio 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
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	Mr. Miles O'Brien, Independent Journalist
Member at Large	Mr. William (Tony) Cole, Vice President and Global Government Chief Technology Officer, FireEye
Member at Large	Dr. Elisabeth Paté-Cornell, Professor and Founding Chair, Department of Management Science and Engineering, Stanford University
Ex Officio Members	Dr. Fiona Harrison, Chair, Space Studies Board (SSB), National Academy of Sciences Dr. Alan Epstein, Chair, Aeronautics and Space Engineering Board (ASEB), National Academy of Engineering

APPENDIX C

NASA ADVISORY COUNCIL MEETING ATTENDEES

NASA Advisory Council Members:

General Lester L. Lyles, <i>Chair</i>	U.S. Air Force (Ret.)
Dr. Penina Axelrad	University of Colorado, Boulder
Mr. Kenneth Bowersox	U.S. Navy (Ret.)
Dr. William Ballhaus	Aerospace Corporation (Ret.)
Dr. Tony Cole	FireEye
Mr. John Borghese	Rockwell-Collins ATC
Dr. Alan H. Epstein, <i>Ex Officio</i>	Chair, Aeronautics and Space Engineering Board
	National Academy of Engineering
Mr. N. Wayne Hale	Special Aerospace Services
Dr. Aimee Kennedy	Battelle
Dr. Elisabeth Paté-Cornell	Stanford University
Dr. Bradley Peterson	Ohio State University (Ret.)
Ms. P. Diane Rausch, <i>Executive Director</i>	NASA Headquarters
Dr. Patricia Sanders	Chair, NASA Aerospace Safety Advisory Panel (ASAP)

NASA Attendees:

Marguerite Broadwell	NASA Headquarters
Elaine Denning	NASA Headquarters
Chris Fitzsimonds	NASA Headquarters
Beverly Girten	NASA Headquarters
William Gerstenmaier	NASA Headquarters
Mike Green	NASA Headquarters
Steve Jurczyk	NASA Headquarters
John Karcz	NASA Headquarters
Mike Kincaid	NASA Headquarters
Marla King	NASA Headquarters
Meredith McKay	NASA Headquarters
A Rowe	NASA Headquarters
Bette Siegel	NASA Headquarters
Jeff Waksman	NASA Headquarters
Michael New	NASA Headquarters
David Walters	NASA Headquarters
Thomas Zurbuchen	NASA Headquarters

Other Attendees:

Francesco Bordi	Aerospace
Ryan Faith	Committee on Science, Space and Technology
	U.S. House of Representatives
Mary Floyd	Ingenicomm, Inc.
Mark Mozena	ULA
Joan Zimmermann	Ingenicomm, Inc.

Dial-In/WebEx Attendees:

Gale Allen	NASA Headquarters
David Balajthy	NASA Office of the Inspector General
Sarah Barber	U.S. House of Representatives
Darren Bedell	NASA
Darrell Branscome	NASA Consultant
Lin Chambers	NASA
A.C. Charania	Blue Origin
Stephen Clark	Space Flight Now
Al Condes	NASA
Nicholas Cummings	U.S. Senate
Patti Curtis	Museum of Science Boston
Keith Cowing	nasawatch.com
Marcia Dunn	Associated Press
James Dean	Florida Today
Anyah Dembling	NASA
Casey Dreier	The Planetary Society
Kristen Erickson	NASA
Ryan Face	Science Committee
Jeff Foust	Space News
Chris Gilbert	VE Consult
Helen Grant	NASA Headquarters
Ellen Graham	NASA Headquarters
Kathryn Hambelton	NASA
Adam Hugo	Public Bridges
Rick Irving	NASA Headquarters
William Kahle	Public Member
Theodore Kronmiller	Law Office
Renee Leck	NASA
Meredith McKay	NASA Headquarters
Richard McKinney	Independent Consultant
Unmeel Mehta	NASA
Gene Mikulka	Talking Space
Sonia Miller	NASA
John Painter	Painter Aerospace
David Parkes	AAAS
Andy Pasztor	Wall Street Journal
Natasha Pinault	NASA
Adam Polhamus	Student, Space Policy Institute, George Washington University
Betsy Pugel	NASA Headquarters
Tony Reichardt	Air and Space Magazine
Michelle Rodriguez	SRI International
David Rubin	
John Rummel	SETI Institute
Martin Ruzek	USRA
Rebecca Salem	
Marcia Smith	spacepolicyonline.com
Mary Sladek, NASA HQ	
Dan Troy	OMB
Andrew Row	NASA Headquarters
Pam Whitney	Science Committee, U.S. House of Representatives
Angela Williams	Ingenicomm
Ashley Wilkins	American Astronomical Society
Ana Wilson	Ingenicomm

APPENDIX D**LIST OF PRESENTATION MATERIAL**

- 1) Aeronautics Committee Report – Mr. John Borghese
- 2) Technology, Innovation and Engineering Report – Dr. William Ballhaus
- 3) Ad Hoc Task Force on STEM Education – Dr. Aimee Kennedy
- 4) NASA Exploration Update – Mr. William Gerstenmaier
- 5) Human Exploration and Operations Committee Report – Mr. Kenneth Bowersox
- 6) Science Committee Report – Dr. Bradley Peterson