National Aeronautics and Space Administration
Washington, DC

NASA ADVISORY COUNCIL

March 28-29, 2018

NASA Headquarters
Washington, DC

MEETING MINUTES

P. Diane Rausch
Executive Director

Lester L. Lyles
Chair

NASA ADVISORY COUNCIL

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

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Meeting Report prepared by
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Call to Order, Annoucements

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

Opening Remarks by NAC Chair

Ms. Rausch introduced General Lyles, who reviewed the afternoon's agenda and led introductions around the table.

NASA Exploration Update

Mr. William Gerstenmaier, Associate Administrator (AA) for the Human Exploration and Operations Mission Directorate (HEOMD), briefed the NAC on Exploration program directions received in the Fiscal Year (FY) 2019 budget, which supports the transition from major development to flight in the Exploration Program. The Presidential Space Policy Directive 1 provided good clear direction, and states that NASA will lead the return of humans to the Moon, followed by human missions to Mars and "other destinations." The Directive is not represented as a line item but is scattered throughout the Agency's budget. In addition to HEOMD, some Exploration funds reside in the Space Technology Mission Directorate (STMD) and some in the Science Mission Directorate (SMD), indicating a truly Agency-wide effort. General Lyles commented that the lack of line items poses a challenge in keeping track of how the different aspects of Exploration fit together. Mr. Gerstenmaier responded that the varied budget allocations force HEOMD to forge tight communication ties in order to remain aware of where the dependencies are, and to maintain a good and appropriate Headquarters-level integration function. He did not feel that the budget diffusion constituted a problem.

The total FY 2019 budget for the Exploration campaign is roughly $10.5B, which demonstrates a real commitment to the Directive. Exploration Mission 1 (EM-1; un-crewed) is scheduled to fly in 2020, and EM-2 (with crews at the Moon) in 2023. The Deep Space Gateway is slated to be in place by 2025. The Agency is about to issue a Broad Area Announcement (BAA) for the Gateway's Power Propulsion

Element (PPE), scheduled to be completed by 2022. The budget also supports a new joint initiative to develop small and mid-size robot landers for commercial lunar landings as early as 2019, a new program to incentivize commercial capabilities in low-Earth orbit (LEO), and a new Exploration Research and Technology (ER&T) account to develop laser communication, green propellant, and precision navigation payloads. Dr. William Ballhaus asked how lunar activities would help to drive down risks for Mars missions. Mr. Gerstenmaier noted there was still much to learn about Mars surface operations, particularly in ascending from surface to orbit, for which HEOMD will do only as much as needed at the Moon. NASA is using the International Space Station (ISS) extensively to test life support systems, which will need to function for three years in a Mars environment. As to the huge need for "spares" and other critical logistics components for Mars missions, testing is being done on ISS: among these projects are inflight maintenance kits, and the use of 3D printers. The crew has been able to 3D-print an X-band antenna on ISS and is also exploring reparability. Dr. Bradley Peterson asked how HEOMD was planning for lunar versus Mars ascent capabilities. Mr. Gerstenmaier explained that ascent parameters for Mars could be modeled based on known variables (gravity, atmospheric density, etc.), but that propulsion would be the real issue; i.e. reliability and the ability to re-ignite an engine.

Mr. Gerstenmaier briefly reviewed the strategic principles for sustainable exploration, remarking that there would be a new emphasis on expanding and clarifying the commercial partnership piece. The other principles remain the same: fiscal realism; scientific exploration; technology pull and push; gradual build-up of capability; architecture openness and resilience; global collaboration and leadership; and continuity of human spaceflight. The goal is to drive an uninterrupted expansion of human presence into the solar system by establishing a regular cadence of crewed missions to cis-lunar space. General Lyles asked if there were any anticipated issues stemming from international partnerships that might pose a challenge to progress. Mr. Gerstenmaier said HEOMD needed to watch this moving forward, as NASA should still seek to be a leader, but probably would not want to put partners in the critical path of a mission. Rather, the Agency should create the compelling missions and see where partners want to participate.

The Exploration campaign has four major elements: an early science and technology initiative; a small commercial lander initiative, a mid- to large lander initiative; and the lunar-orbital platform, the Deep Space Gateway. The first element entails examining old lunar samples with new technology, an effort led by SMD. The first lunar flight will include 13 CubeSats from SMD and STMD, with science and technology payloads. Small commercial landers will be developed under HEOMD for the Lunar Catalyst and Tipping Point programs, and also under SMD. The mid- to large lander development efforts looks toward a human-rated lander. These will begin with HEO/SMD 500kg to 1000kg landers, followed by an HEO/SMD-developed human descent module lander (5000 to 6000kg) in 2029, and SMD Mars Robotics (rovers, sample caching). HEOMD is planning on Space Launch System (SLS)-based Orion lunar orbital flights starting in 2023.

The near-term engagement schedule includes much precursor work, contracting, and determining commercial acquisition strategies, which will entail releasing Requests for Information (RFIs) to industry on advancing lander capabilities, propulsion, and related topics. There will be Exploration-relevant activities in STMD, including an open call that should receive some proposals by the end of May 2018. Mr. Gerstenmaier emphasized that there needs to be some benefit to the commercial sector in these activities as well, and HEOMD must explore where commercial partners can see their own revenue generation possibilities. General Lyles remarked that planning will also need the involvement of other parts of the Government, including Congress, and that it was good to see near-term planning being done early in the process. Mr. John Borghese asked about distinctions between Moon and Mars landing schemes (no atmosphere vs. atmosphere) and asked if there were any plans to use airfoils. Mr. Gerstenmaier remarked that while Entry, Descent and Landing (EDL) would obviously be different for the two bodies, hazard avoidance and touchdown technologies are similar. There is some commonality in the final approach. The Moon missions won't employ parachutes and hypersonics. Mr. James Reuter,

Acting Associate Administrator for STMD, said his Directorate did plan a hypersonic demonstration for Earth atmosphere.

EM-1 is scheduled for December 2019, with about two to four months of risk incorporated into that number. Mr. Gerstenmaier felt the date was valid, from a planning point of view. The primary critical path for EM-1 is through the European Service Module, which is scheduled to ship to the U.S. in April 2018; this shipment will probably slip to July 2018. The schedule is being driven by secondary U.S. suppliers to the Europeans. There are also some further concerns about the industrial base and sub-tier suppliers, particularly with respect to thruster valves. HEOMD is trying to isolate the problem. These companies may not have built these parts in some time; the situation constitutes a lesson learned for NASA. Mr. Wayne Hale asked if the supply chain problem was indicative of degradation in the U.S. industrial base. Mr. Gerstenmaier thought this particular manufacturing sector was coming out of a valley where there had been little development for some time, and now that there is large demand, the delay is reflective of the impaired industry's ability to ramp up. Mr. Hale remarked that many of the smaller machine shops went out of business when the Space Shuttle program ended, leading to similar problems. Mr. Ballhaus observed that vertically integrated companies can easily lose core competencies in subcontracting. Mr. Gerstenmaier agreed that this was a U.S.-wide issue. Much work in the engine section has also been needed in preparing for EM-1; assembly for the first time is not easy. Tanks are being taken all the way to failure in an effort to validate models, and to learn as much as possible from these early tests. The last critical path is software at Kennedy Space Center (KSC). General Lyles said he hoped lessons learned on manufacturing technology and subcontract management were being documented. Mr. Gerstenmaier noted that HEOMD is indeed gathering lessons learned.

HEOMD is studying the requirements for sending vehicles to distant retrograde orbit (DRO), where an object left there stays for perpetuity; it will be necessary to know how to get in and out of DRO. One CubeSat project involves a small lander on the Moon that uses a solid rocket motor, which can perhaps be used to land small payloads. Such a lander will need a different heat shield. The total mission will be 25 days.

SLS lift capabilities are evolving toward large payload volumes, and lots of trans-lunar injection (TLI) capabilities. The associated Orion capsule is being envisioned as a "space tug" that can tow habitation modules and other elements of the Gateway system. It would be unique to have Orion and significant cargo in the vicinity of the Moon in one launch. The plan is to augment the system with commercial cargo flights (up to two per year), electric propulsion (the PPE element) can change the way NASA does business: it can support a platform that will orbit the Moon, or send landers to the Moon in preparation for a human lunar return.

Mr. Borghese asked what the disposition of ISS would be in 2030. Mr. Gerstenmaier said NASA was in discussion about making parts of ISS available for commercial use, and perhaps demonstrating some modules at different inclinations. HEOMD will query the private sector as to how it might use LEO, then determine how NASA can help move commercial plans forward. Dr. Peterson said he had observed a good deal of science interest at a recent Deep Space Gateway conference in Colorado, as well as a broad range of demand: telerobotics on the Moon, deep space astronomy on the surface of the Moon, and exciting possibilities for building space telescopes in deep space. Asked how the work load and workforce were faring under the new push for Exploration, Mr. Gerstenmaier reported that people, resources, and morale were all positively oriented. The team is fully engaged in new work on lunar surface projects, as well as in serious acquisition activities for the Gateway. The workforce is aware that more work is coming and is getting organized. It is an exciting time for everyone and there is a lot of work behind the scenes. Hardware is being built, and more importantly, validations and verifications are taking place in the engineering and technical authority base.

The Council congratulated Mr. Gerstenmaier on his recent election to the 2018 National Academy of Engineering.

Human Exploration and Operations Report

Mr. Kenneth Bowersox, Chair of the Human Exploration and Operations Committee, provided an update to the NAC. The Committee last met on March 26-27, 2018, and in addition to its major topics, zoomed in a bit on Commercial Crew. As many Commercial Crew technical issues are proprietary to each provider, the Committee had some non-public fact-finding sessions, wherein members were able to get a good idea of the types of issues being worked. The team's reaction to these sessions was generally positive.

On ISS, the latest increment crew is comprised of one Japanese Space Agency astronaut, three NASA astronauts, and two Russian astronauts. The crew is performing record hours of payload work, and also includes the efforts of educator astronaut Ricky Arnold, a solid contributor to the astronaut corps. All of the increments have been quite busy, with multiple Soyuz flights. Currently there is an emphasis to testing on ISS those technologies which could benefit Exploration. There is an upcoming technology demonstration for carbon dioxide removal, pertaining to thermal amine scrubbers, which experience unique stressors in microgravity. ISS is also testing an on-site commercial bioanalyzer, a chip that analyzes saliva samples to monitor stress levels and appetites. The crew is testing a SG100 Cloud Computing Payload, a technology demonstration of a radiation-tolerant computer capability for high-data science applications. The object of the test is to prove Technology Readiness Level 9 (TRL 9). Space radiation remains an issue for crew; the Human Research Program (HRP) Path to Risk Reduction is considering that NASA may have to accept additional risk as it moves crews out to Mars. There are also food risks, and cognitive/behavioral risks associated with long-term space flight. Mr. Hale noted that much radiation work can be done in ground facilities. Mr. Bowersox added that HRP manages risk analysis activities inside HEOMD; to this end, the HEO Committee also received a briefing from NASA's Space Life and Physical Sciences Research Division, which is guided by the Decadal Survey and mid-term assessments.

On ISS, cargo is now provided through two commercial suppliers, Orbital ATK and SpaceX. Sierra Nevada Corporation will be joining the cargo providers with a winged, cargo-return vehicle that will operate at a lower acceleration level. The first flights are expected in 2019. Dr. Patricia Sanders, Chair of the NASA Aerospace Safety Advisory Panel (ASAP), stated that ASAP had a very positive site visit with Sierra Nevada Corporation in Fall 2017. Both SpaceX and Boeing are scheduling un-crewed test flights for Orion this year (2018). Mr. Bowersox stated that he expected that crewed flight tests will be delayed somewhat. Mr. Borghese asked if so many schedule delays were normal. Mr. Bowersox noted that as programs mature, they schedule more tightly. In the early phases of a program, schedules tend to be aggressive, and rely on "earliest achievable dates." He conceded that not everyone likes this approach. Dr. Sanders remarked that while provider dates tend to be optimistic, NASA program officials may harbor different (more realistic) internal beliefs. Commercial providers do adjust their dates with each quarter. Mr. Gerstenmaier agreed that one should recognize that the dates provided by contractors must be accepted with a dose of reality. He pointed out that at the outset of commercial cargo planning, NASA stockpiled two years of cargo on ISS, ahead of the optimistic expectations of the contractors. Culturally, NASA does not want to unduly push the schedule. Dr. Sanders added that ASAP had been encouraged to see that the program office is doing the right things to enable the program to fly when ready.

Mr. Bowersox elaborated further on the Orion program and SLS, noting that there is much work in progress in terms of certifying engineering systems, launch towers, service platforms, and the like. Mr. Bowersox felt that the Presidential Space Policy Directive 1, and the synchrony between the Administration, Congress and NASA, have all been very good for the timing of Exploration activities,

while acknowledging the strategic principle of fiscal realism and flat budget growth. The HEOMD strategy of establishing deep space certification requirements and standards is being worked very hard. HEOMD is working particularly hard on developing standards in avionics, communication, power, environmental control, and life support systems, to enable work with both international and commercial partners. These standards, when finalized and accepted, will allow partners to work on their own programs while also enhancing their interoperability with NASA's Deep Space Gateway. Dr. Peterson observed that commonly accepted standards also make everything cheaper. Mr. Bowersox agreed, adding that HEOMD is talking about using the Gateway as a temporary refuge for all participants. Commercial entities and international partners have three months to respond to NASA's push to develop standards. This call can be found at: [https://www.internationaldeepspacestandards.com]. Mr. Gerstenmaier said he hoped for substantial feedback by Fall 2018 (the call went out on March 1, 2018). General Lyles asked if NASA would go to ISO standards. Mr. Gerstenmaier thought not. Mr. Borghese commented on one other key domain for standards: autonomous systems. Mr. Bowersox said NASA already employs a docking standard. Mr. Gerstenmaier thought there was no standard yet on autonomous systems, and that perhaps language to this effect could be included in future robotics calls.

The Deep Space Gateway is envisioned as a portal for future Solar System travel and will inform transport to Mars, and will perhaps be an element of Mars Sample Return (MSR). The first element of Deep Space Gateway development is the power and propulsion bus. The first bus may well be commercial. The next modules are habitation, logistics, and airlock. Five different companies are competing in concept investigations for PPE, thus it is possible that NASA will have access to more than one PPE bus.

Mr. Bowersox mentioned the International Space Exploration Coordination Group (ISECG), a nonbinding voluntary forum of 15 nations where space agencies share information, inform diplomatic agreements, and set up cooperative agreements, which is aligned with NASA's Exploration plans. Common goals are to expand the human presence into the Solar System, understand our place in the Universe, engage the public, and stimulate economic prosperity. ISECG is developing a revised Global Exploration Roadmap that will document these goals, which should be of interest to NASA as it plans for the future of ISS. ISS transition principles are still under discussion and based largely on the need for continuity of access to LEO. Dr. Ballhaus asked how the ISS transition would occur economically. Mr. Bowersox said that this was still a big question, and that NASA is working to obtain feedback from industry as what they might contribute. The Agency is also discussing NASA's future need for access to LEO beyond 2024, especially for training astronauts for long-duration space missions. Mr. Bowersox felt it was possible that ISS may become a government-owned, contractor-operated (GOCO) concern. To that end, the HEO Committee proposed a near-term planning recommendation. After deliberation, the Council approved the following recommendation to the HEOMD Associate Administrator regarding metrics for ISS transition and fleet leader approach for critical exploration systems:

> *The NASA HEOMD should formulate a set of metrics to guide ISS transition. Suggested metrics include the minimum amount of run time for fleet leader exploration systems in the areas of life support, propulsion and avionics.*

Mr. Bowersox noted that the HEO Committee needs to deliberate further on the question of how much run time is needed in space in to support fleet leader exploration systems. Other critical questions include ensuring commonality in systems, the ability to print parts (in space), and when or how to decide to give up LEO operations.

The HEO Committee issued a number of observations, one noting the presence of good support that will enable NASA to carry out the Presidential Space Policy Directive 1, and another highlighting the maturity of the cis-lunar exploration campaign, which is being done in a manner that allows participants some

independence. The HEO Committee also observed that there were potential benefits in NASA looking at different program evaluation products, which might help the Agency optimally tune its multi-decadal capability development efforts. Lastly, the HEO Committee observed that programmatic flexibility in the Commercial Cargo program had resulted in the provision of essential services at a cost lower than previously possible, and that such an approach is applicable elsewhere in the Agency. With regard to NASA's push in Exploration technologies, Mr. Borghese commented that novel programs are likely to run into novel problems, which could be mitigated by having a management reserve or innovation fund. Mr. Gerstenmaier said it was hard to determine how much reserve to hold for this type of development; carrying funds in maintenance and operations systems is difficult to do in Government programs. Dr. Sanders, citing her experience with the Theatre High Altitude Atmospheric Defense (THAAD) test program, noted that extra testing was built in and funded in advance, but with the accompanying disadvantage of inflexibility.

The HEO Committee raised some concerns with NASA's approach to governance, which was seen as potentially slowing effort and resolution of critical issues; it was felt that this situation might need some high-level attention. Asked to provide an example, Mr. Bowersox detailed an instance of disagreement among safety, medical, and technical authorities, which needed to be worked up to the NASA Associate Administrator level, who then has to break the tie. These types of issues get slow-pedaled to prevent them from getting to upper management. Dr. Sanders and Dr. Ballhaus agreed that the right people have to be in the room in order to make a decision.

Another HEO Committee concern centered on the timing of the first crewed launch in the Commercial Crew Program. If there are delays, U.S. presence aboard ISS could be lost if availability of commercial transportation to ISS is delayed beyond about 24 months. Mr. Bowersox noted that NASA has since taken actions and has gained an additional three months of margin. Finally, the HEO Committee expressed concern that any efforts to reorganize HEOMD, which is currently working well, could increase risk levels in NASA's human exploration program.

Mr. Bowersox detailed some future special topics for the HEO Committee, and highlighted a new addition: Mars transport maintenance, parts commonality and redundancy strategy.

Aeronautics Committee Report

Mr. John Borghese, Chair of the Aeronautics Committee, provided an update to the Council. U.S. aviation exports account for $118B of business, and therefore constitutes a very important part of the economy. NASA continues to advance the state of the art in aviation technology, and appropriately so. The Aeronautics Committee now has six committee members and will add three more by its next meeting. The previous Aeronautics Committee meeting addressed four topics, including the contents of the FY 2019 budget. Over the past 100 years, NASA's efforts in aeronautics have helped to improve the safety and efficiency of air travel by leaps and bounds. Air travel is now the safest mode of travel (one incident per 50 million miles). A new era in flight is emerging that is in no small way supported by the vision of NASA's Aeronautics Research Mission Directorate (ARMD), which has stimulated pioneering technologies and systems such as integration of Unmanned Aircraft Systems (UAS) into U.S. air traffic management, a move supported by Congress; electric aircraft; system-wide safety; and supersonic aircraft. These efforts are also enticing engineers into the field, creating a new "Silicon Valley" of aeronautics engineering, constituting a dramatic change in aviation. Asked if the ARMD Associate Administrator, Dr. Jaiwon Shin, had originated some of these innovations, Mr. Borghese said Dr. Shin had certainly originated some of them and encouraged the rest.

The FY 2019 budget for ARMD supports the completion of the X-plane Critical Design Review; increases funding for fundamental research in hypersonics, recognized as a key area by the Department of

Defense; continues to develop promising subsonic aircraft technologies; supports the development of electronic propulsion systems for the X-57; supports the integration of UAS operations into the National Air Space; provides new Air Traffic Management (ATM) tools to increase safety; and supports the completion of an advanced composites project (in the last year of a five-year program). Mr. Ballhaus asked if the budget support engineering methods in computational fluid dynamics (CFD) and hypersonic computer codes. Mr. Borghese said NASA would be largely responsible for modeling in hypersonics research, while the building and launching of systems would be handled by the Air Force Research Laboratory (AFRL) and the Defense Advanced Research Projects Agency (DARPA). General Lyles felt the NAC ought to keep a special eye on NASA's role in advancing hypersonics.

Mr. Borghese presented a proposed Aeronautics Committee finding on ARMD's portfolio, which endorsed the research areas of autonomy and electric vehicles, two new areas for NASA. After Council deliberation, the Council approved the following finding to the ARMD Associate Administrator:

> *The Aeronautics Committee agreed that the NASA ARMD overall portfolio and strategy are aligned to support the future of aviation by being the enabler for new vehicles and airspace. In particular, the Committee endorses research in the area of autonomy and electric vehicles. The Committee also believes that ARMD research should be directed in areas that are not being addressed by commercial industry and other government agencies such as the certification of autonomous systems and the airspace management and other certification technologies needed for these new classes of vehicles.*

The Aeronautics Committee also presented a proposed finding on the naming of the Real Time Safety Assurance System, which stemmed from an ARMD request to the National Academies to develop a research agenda that would identify challenges and identify high-priority research areas for NASA. Some outcomes from the National Academies included a finding that supports replacing "real time" with "in-time," and to replace "safety assurance system" with "safety management system." The Aeronautics Committee agrees with the finding that considers safety management to be a more comprehensive approach than safety assurance. Thus, overall, the Aeronautics Committee supports the change of name and concept to "In-time Aviation Safety Management." The National Academies also found that the In-time Aviation Safety Management System (IASMS) should be based on a concept of operations that considers multiple architectures, and that the system should be developed within a three-decade program. As a result, the Aeronautics Committee proposed a finding regarding the system-wide safety report, and after Council deliberation, the following finding was approved for the ARMD Associate Administrator:

> *The Aeronautics Committee found that the System-Wide Safety (SWS) project has many facets and needs to identify which ones provide a real payoff and focus on specific areas. They understand that this project is in formulation and supports ARMD's intent to focus on topics where NASA can provide unique and important contributions to the safety of the National Airspace System (NAS) as traffic density increases and new entrants enter the airspace. The Committee also believes that SWS should address the cyber security element of NAS management and clearly define yearly objectives.*

Mr. Borghese turned to advanced materials and structures, relating that ARMD had chartered a small focus team to envision a future strategy and investment for materials and structures in the FY 2020-2030 time frame. The focus team developed specific guidelines and wished to obtain feedback from the NAC to indicate whether or not they are on the right track. Recent accomplishments in this area include the development of vanes and blades that increase aircraft efficiency, and advances in shape memory alloys. ARMD recognizes a need to look at interrelated cross-cutting areas, such as embedding antennae into fuselages, and creating adaptive structures such as wings that change shape with application of voltage.

The Aeronautics Committee proposed a finding regarding advanced materials and structures strategy. Dr. Epstein noted that NASA does not have the resources to do everything for aerospace materials, and that the Aeronautics Committee could help NASA by narrowing ARMD's focus based on the resources available. With regard to incremental improvements to aviation, NASA has been a key player. He stressed that novelty should not be confused with value; NASA needs to identify what is most useful here. How do you certify composite structures? How do you use analytical tools and testing techniques to do this? Dr. Epstein added that analyzing non-isotropic structures is another area, whereby talking with industry might reveal the areas in which NASA can have the best impact. Mr. Borghese agreed with Dr. Epstein and said the finding has some of these concerns embedded. Mr. Ballhaus suggested adding language on the need to gather statistics on optimal designs and the manufacturing conditions that affect material properties. Dr. Epstein further suggested that ARMD look to where NASA has the people and the facilities (wind tunnels, e.g.), and select areas where NASA has strength, and where research can play a key role for industry. General Lyles suggested minor alterations to the finding to reflect the Council discussion. After Council deliberation, the following finding was approved for the ARMD Associate Administrator:

> *The Committee appreciated being part of the initial planning of this project in order to provide feedback in its infancy. The initial planning has displayed insights into the interrelationship of core areas, including advanced manufacturing, computational materials and structures, multifunctional materials and adaptive structures, and the issues of qualification, certification and lifecycle sustainment. The Committee believes that this research is very important. There is significant multi-agency investment in the government's new manufacturing initiatives that NASA should evaluate and integrate with the national endeavor in this area and focus on specific needs of aviation where there are gaps in the research.*

The Aeronautics Committee also considered how electric propulsion can improve highly optimized single-aisle aircraft, enable new configurations of vertical take-off and landing (VTOL) aircraft, and revitalize the economic case for small short-range aircraft. Dr. Epstein commented that the "sweet" spot for electric propulsion is in the very-small aircraft arena and that he did not believe electric propulsion can reduce carbon dioxide emissions, given that current aircraft are more efficient than current power grids. Moreover, new capabilities like VTOL would require more energy than electric propulsion can provide. The other factor for NASA to consider is what people actually care about in aviation: price and noise. NASA's work on noise has been the foundation of noise reduction for 50 years. Dr. Epstein believed that NASA could actually eliminate the problem over the next 30 years, incrementally. Mr. Borghese agreed that good batteries do not begin to reach the kilowatt-hour level of fuel, but that batteries can be used to boost power during VTOL takeoffs and landings.

Ensuring U.S. leadership in subsonic transport technology depends on getting fuel and noise down considerably with blended-wing bodies, and by transforming propulsion with boundary layer ingesting propulsion technology. The Aeronautics Committee was very impressed with ARMD's hybrid electric system research activities and presented a proposed finding on this topic. Dr. Epstein cautioned that "apples to apples" comparisons between an electrically enabled configuration and a mechanically enabled configuration have not yet been done. Mr. Borghese noted that NASA is funding research on the efficiencies and failure points of the electric propulsion systems, but that the Aeronautics Committee does recognize that industry is not focusing on certification. General Lyles asked that language on certification be added to the finding. After Council deliberation, the following finding was approved for the ARMD Associate Administrator:

> *The Committee was impressed with the direction that the electric aircraft technology team is headed and how they have used the low carbon study results to guide that direction. The Committee also suggested that NASA's goal be to uncover the regulators primary focus areas, inspiring solutions for validation, verification and certification while working with industry to*

address these challenges. The Committee was very impressed with the hybrid electric system research activities and encourages the project to focus on modeling the efficiency of the various configurations.

Mr. Borghese concluded by briefly summarizing next steps on the Aeronautics Committee Work Plan, which will include a discussion of Air Traffic Management-X (ATM-X), a future vision for the 2050 Air Traffic Management system.

Ad Hoc Task Force on Science, Technology, Engineering and Mathematics (STEM) Education

Dr. Aimee Kennedy, Chair of the Ad Hoc Task Force on Science, Technology, Engineering and Mathematics (STEM) Education, briefed the NAC on its latest meeting. The Task Force held a teleconference on March 20, 2018, and discussed the NASA Office of Education's implementation of the Business Services Assessment (BSA). The new posture of the Office of Education, which was once operating in parallel with the NASA Mission Directorates, has transformed into Agency-driven Education.

Dr. Kennedy stressed the Task Force's diversity and how it was impressed by the progress it had witnessed at NASA to date, including completion of reviews of past performance, benchmarking other Federal agencies, literature reviews, interviews, and compiling an expert panel. Currently, the Office of Education is considering internal efficiencies and external metrics in STEM workforce development.

The Task Force was also pleased to hear about new Education signature programs, and to see that the internship program has new public face, and that the Space Grant now has a reinvigorated approach. The new internship website is easy to navigate [intern.nasa.gov] and considerably more inviting than the previous website. The Task Force noted more face time with Mission Directorate leadership, and some reallocation of time with people who have had success in reaching out to underserved populations in other areas.

The Task Force applauded the Year of Education on Station (YES) project and its ability to reach many schools through downlinks and social media, particularly through the National Science Teachers Association. In addition, the 2018 TEAM II solicitation has been revised to reduce the number of pages, and to require that proposers demonstrate that they have 30 partners. Currently the solicitation is focusing on Human Exploration beyond LEO, and Small Steps to Giant Leaps, topics that coincide with the 50th and 60th anniversaries of NASA (Apollo Moon landing and NASA agency establishment, respectively).

To recognize the progress in these areas, the STEM Task Force proposed a comprehensive finding on continued progress and strategic alignment in the NASA Office of Education. After Council deliberation, the following finding was approved for the NASA Administrator:

The Office of Education continues to demonstrate progress toward implementing the recommendations of the Education and Outreach Business Services Assessment (BSA). The actions taken by the Office of Education to improve the strategic alignment, implementation, and evaluation of their STEM engagement activities have happened swiftly and are impressive.

The Office of Education has undertaken a comprehensive approach to researching and developing an evaluation program. The Office has also realigned the Space Grant and Internship programs to be more closely aligned with the mission and vision of NASA. Another step the Office has taken is to use the unique situation of two educators on the International Space Station (ISS) to name this year the "Year of Education on Station". Finally, the Office realigned the informal institution solicitation to be more focused and streamlined.

In summary, specific examples of the impressive progress include:
– Significant progress toward evaluation of NASA STEM education investments
– Realigned signature programs (i.e., Space Grant and Internship)
– Amplifying NASA profile with "Year of Education on Station"
– TEAM II solicitation optimized

General Lyles asked if it were to be assumed that everything in the NASA Office of Education would be carried over to the new proposed Office of STEM Engagement. Mr. Mike Kincaid said there would definitely be a budget implication to the carryover, and that NASA was in the midst of making choices. He did not believe that any large items were being lost.

Dr. Kennedy re-introduced a prior Task Force recommendation to elevate the Ad-Hoc Task Force on STEM Education to become a NAC regular committee:

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

The Council tabled this recommendation, and indicated it should be held for consideration by the next NASA Administrator, following confirmation and appointment.

Remarks by NASA Acting Administrator

The Council welcomed Mr. Robert Lightfoot, Acting Administrator of NASA. Mr. Lightfoot updated the NAC on NASA's latest activities, noting that he would be retiring from the Agency at end of April 2018, a bittersweet decision that includes a much gratitude for the opportunities he had been given. He noted he had appreciated the advice he had received from the NAC over the last 14 months. He further noted that Mr. James Bridenstine's nomination as new NASA Administrator had been re-submitted and now awaits a full Senate vote. Mr. Jeff DeWit has been appointed as the new Chief Financial Officer (CFO); Mr. Lightfoot thanked Mr. Andrew Hunter for his role as Acting CFO, pointing out that NASA had achieved another clean audit under Mr. Hunter's watch. Dr. Lisa Pratt has stepped into the role of new Planetary Protection Officer (PPO). Mr. Lightfoot acknowledged the passing of Apollo and Space Shuttle Astronaut John Young, who left a phenomenal legacy and was a great mentor. He reported he had attended the International Space Exploration Conference meeting in Tokyo and was amazed at how many countries had attended (45), adding that NASA can take advantage of this interest, particularly in developing deep space interoperability standards. The second meeting of the National Space Council (NSpC) took place on February 21, 2018.. The NSpC received actions on streamlining regulations with both the Departments of State and Commerce, and on how to partner internationally. Mr. Lightfoot noted that Vice President Mike Pence is the chair of the NSpC, and is deeply engaged with it..

NASA held its Day of Remembrance on January 25, 2018,, which also marked the 15th anniversary of the Space Shuttle Columbia accident on February 1, 2003. A long overdue memorial to the Apollo I crew has also been approved by Congress for Arlington National Cemetery. A new NASA logo has been released to celebrate NASA's upcoming 60th anniversary on October 1, 2018. The most recent budget allocation allowed NASA to receive an effective increase of $300M to support a renewed focus on human exploration and a return to the Moon, to engage with the emerging private sector for LEO, and to support cutting edge science in Aeronautics. The Presidential Space Policy Directive 1 provided strategic support for SLS and Orion as a transportation backbone, and for robotic landers as scouts. The goal is to operate from the Deep Space Gateway, which eventually will be used as a jumping point to Mars. Much work remains in advancing entry, descent and landing, radiation safety, and life support systems. In science, SMD is launching many missions; Congress has also shown strong support for the Wide Field Infrared

Space Telescope (WFIRST). In ARMD, the announcement of the Low Boom Flight Demonstrator (LBFD) will occur very soon and will likely draw much attention from the education perspective, to help to grab a different community of interest. An increased emphasis on UAS and hypersonic research is also welcome. NASA recently selected 128 technology proposals through the Small Business Innovative Research (SBIR) program and featured 49 technologies in the latest issue of NASA's *Spinoff* magazine.

NASA is focused on seven priority areas in global cooperation, including avionics, power, robotics, and thermal systems, all of which emphasize the importance of creating deep space standards for interoperability. The Geostationary Operational Environmental Satellite (GOES)-S mission was launched earlier this year and has inspired two creative "home planet" proposals. The James Webb Space Telescope (JWST) launch has been delayed to May 2020; Tom Young will be holding an independent review to confirm the feasibility of the proposed date. NASA launched a Heliophysics mission, Global-scale Observations of the Limb and Disk (GOLD) on January 28, 2018; this is a hosted payload on a commercial satellite. Two finalists for robotic missions were recently selected as well: one to Titan and one to comet 67P/Churyumov-Gerasimenko, the target of the European Rosetta mission.

Mr. Lightfoot paused to recognize Dr. Bradley Peterson for his outstanding service as the Chair of the NAC Science Committee, and commended him for providing a balanced view of science at NASA. On the occasion of Dr. Peterson's final NAC meeting, Mr. Lightfoot presented Dr. Peterson with NASA's Exceptional Service Medal, one of NASA's highest honors.

General Lyles asked Mr. Lightfoot for his opinion on how to incentivize industry to participate in LEO activities. Mr. Lightfoot felt that NASA would always need access to LEO, but that the question of how much of a tenant NASA will be remains to be answered. There are options, but the challenge today is that LEO does not necessarily equal ISS. The Broad Area Announcement will hopefully provide some solutions. NASA must be careful to avoid assuming that ISS money will be free to spend in other areas. General Lyles remarked that he was happy to see the budget request's new emphasis on hypersonics, as NASA has a unique role in this area. He noted also that the Missile Defense Agency received a large increase in this area, and he hoped NASA could step up to the challenge. Mr. Lightfoot agreed, adding that NASA has unique facilities, and a unique skill set in its people, particularly in systems analysis. Hypersonics is the only technology that will get a vehicle from Single Stage to Orbit. Mr. Bowersox noted that the HEO Committee has expressed concern about obtaining crewed vehicle technology, in that governance could slow down the process. Mr. Lightfoot acknowledged the concern and said the big problem is that people are not bringing up issues as they come up. He thought the Agency would have to flex its risk acceptance muscles a bit, but should be transparent about it. The Agency cannot be afraid of dissenting opinion; it needs to be open about it to impact decision velocity. Mr. Ballhaus commented that if issues can be brought to the level of the authority that has the resources to mitigate the risk, they can be resolved more quickly. Mr. Lightfoot said that while the monthly NASA Headquarters reviews are useful, NASA still has to get people to speak up; but he did note that the various independent technical authorities (ITAs) are doing their jobs very well.

General Lyles and the Council expressed their deep gratitude for Mr. Lightfoot's tremendous leadership, and as someone who can "do the job and take care of the people." General Lyles commended Mr. Lightfoot's great humility and sense of humor with appreciation.

March 29, 2018

Call to Order, Announcements

General Lyles called the meeting to order, and Ms. Rausch provided some administrative reminders for the day.

Opening Remarks

General Lyles reviewed the day's agenda, after which NAC members re-introduced themselves. Mr. Hale stated for the record that he endorsed Mr. Gerstenmaier's HEOMD presentation and those from the HEO Committee, saying his sense is that the plan is a good plan, and that HEOMD should stay the course. General Lyles agreed that HEOMD possesses a cohesive strategic plan for human exploration, and that guidance from Congress and the Administration puts more impetus on the HEOMD program. Mr. Borghese raised one question: it looks like the Exploration plan is contingent on transferring some of ISS cost to industry: how will that work, and what will happen if it doesn't happen? General Lyles said that HEOMD recognizes this as a risk area and that future planning will depend on the response from industry. Mr. Bowersox commented that there is a sense that there will be some provision of LEO by industry, and that NASA may have to use a different platform after 2025 if ISS is not commercially operated. Meanwhile, NASA is trying to figure out what the costs will be in various scenarios. One of the possible markets is countries that do not have a space program. Mr. Ballhaus felt one wild card might be space tourism. General Lyles felt that the opportunities could inspire innovation, just as years before, the idea of treating ISS as a National Laboratory for the world was ultimately realized. Dr. Epstein commented that the commercial sector might be discouraged by the presence of government restrictions in a GOCO partnership for ISS. Mr. Ballhaus likened the process to turning over air bases to the local community, where they subsequently became airports or industrial parks. The Council briefly discussed the ramifications of using the Moon to get to Mars, and how to achieve clarity on how this might be done.

Public Input

No public comments were noted.

President's FY 2019 Proposed Budget for NASA

Mr. Andrew Hunter presented the details of the FY 2019 President's Budget Request, which codifies Presidential Space Policy Directive 1 and provides $19.9B to NASA. It is a good budget that includes a last-minute addition of $300M due to the removal of sequester caps. The budget provides $10.5B of funds that are intended to set lunar exploration activities in motion. Budget refocusing usually means redistribution, thus the FY 2019 Budget Request calls for the termination of WFIRST, a reduction in the Education program, and the termination of five Earth Science missions. The new budget calls for a launch of an un-crewed Orion vehicle by 2020. The budget is still dependent on partnerships and introduces the Lunar Orbital Platform Gateway, supported electric propulsion (SEP) technology developed by STMD, that will lead to progressively more capable robotic lunar missions. The budget also begins the transition of ISS to end government support by 2025, and a new $150M program to encourage commercial LEO. Industry inputs will be included in guiding the new program. Exploration of the Solar System continues with the Mars 2020 rover, the launch of the Europa Clipper in 2025, accompanied by a research program that supports over 10,000 U.S .scientists with over 300 grants. The Earth Science Radiation Budget Instrument (RBI) will be terminated, while the JWST launch will be delayed to 2020. WFIRST will be cancelled due to its significant cost; its funds will be infused into other Astrophysics projects. The budget also integrates space technology investments into HEOMD for new robotic and human exploration,

supports ARMD's LBFD, redirects the Office of Education to new initiatives, and strengthens cybersecurity measures to safeguard critical systems and data.

Anticipated accomplishments in 2019 include the final steps in assembly and testing of JWST, the completion of Commercial Crew milestones to begin operation in 2019, the delivery of several instruments delivered to the Mars 2020 mission, along with other activities in the Heliophysics and Astrophysics Explorer program, and in the Earth Science Venture Class Suborbital strand. General Lyles suggested that in terms of balance between Aeronautics and space activities, Mr. Hunter might consider a separate chart for the ARMD FY 2019 budget to clearly reflect the balance.

The budget will impel some name changes: Exploration Research and Technology (ER&T) will replace the Space Technology Mission Directorate (STMD) line, and will include the Human Research Program; this change makes more money available for space technology in the Agency. LEO and Spaceflight Operations include ISS, Space Transportation, Space and Flight Support, and Commercial LEO Development. JWST has been placed back under the Astrophysics line. The out-years remain flat, but NASA will continue to request inflation increases. Asked what drove the integration of some budget lines, Mr. Hunter said that appropriation accounts and themes reflect that Exploration is the highest priority, but also reflect that Science is quite healthy. Reductions usually indicate money moving into the Exploration accounts, which probably accounted heavily in the decision to terminate WFIRST.

NASA mission launches in FY 2018-2023 include three SMD Missions of Opportunity to the Moon, and Space X and Boeing certification flights (crewed and uncrewed). The Lunar Exploration Campaign will help NASA progress from LEO to cis-lunar space, and support research to inform future Mars missions. The plan reflects much impressive coordination between STMD, SMD and HEOMD. The Lunar Exploration Campaign includes $200M year for lunar landing activities, and about $50M per year to prepare for Mars Sample Return. ER&T is funded at the $1B level in 2019, and includes a laser communications relay demonstration, SBIR funds, CubeSat development, and SEP transfusion into a Power Propulsion Element (PPE) for the Deep Space Gateway. A total of $1.4B is slated for ISS research and operations; about $1.1B of this amount is for operations alone.

Space Transportation includes $2.1B for certification of cargo flights. LEO and Spaceflight Operations provides $904M for mission critical communications and related lines. A new line of $150M is in place for assisting commercial space industry. The Earth Science Division (ESD) will see an increase from the FY 2018 level, along with the proposed termination of five ESD missions carried over from the previous PBR. Every theme in SMD now has a CubeSat line (about $70M). Planetary Science is funded at $2.2B, and supports the Double Asteroid Redirection Test (DART), Near-Earth Object Observations (NEOO) Program, the Europa Clipper, Mars 2020, and 10 other planetary missions, including the Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-Rex) mission to the asteroid Bennu, and the New Horizons Kuiper Belt object flyby scheduled for 2019.

The Astrophysics budget fully funds the Stratospheric Observatory for Far Infrared Astronomy (SOFIA). Heliophysics is stable at $691M and supports the continuing Solar Orbiter Collaboration mission with the European Space Agency. Thanks in part to an increase in the 2018 budget directed by Congress, the ARMD budget supports LBFD, hypersonics funding, X-57, UAS operations and ATM tools. SMD's Science Activation Program will continue at $44M; including scholarship and outreach activities. A total of $2.75B is budgeted for security, construction, and environmental remediation, although the main stress in funding will be on Information Technology (IT) and cybersecurity.

NASA 2018 Strategic Plan

Mr. David Walters, NASA Office of Chief Financial Officer (OCFO), briefed the NAC on details of NASA's new 2018 Strategic Plan. The Strategic Plan was released on February 12, 2018, concurrent with the FY 2019 President's Budget release and the FY 2019 Performance Plan release. Its primary driver is the Government Performance and Results Modernization Act (GPRAMA), which mandates that Federal agencies produce plans every four years to establish goals and objectives upon which the Agency grades its activities. The Strategic Plan is created by OCFO with support from all the NASA Mission Directorates and Offices.

The Vision and Mission statements have been revised and are organized around four themes, which in turn feed into timeless strategic goals. The Strategic Plan received implementation guidance requirements from the Office of Management and Budget (OMB). This year marks the first time under the GPRAMA framework that a Strategic Plan was published during a Presidential transition year; NASA also had to take into account future NASA Administrator changes. In developing the Plan, the OCFO relied on clear guidance from NASA leadership and used top-down and bottom-up approaches in aligning the strategic goals to the four themes and six overarching critical elements throughout the document. The Plan followed a standard development process, and its details were reiterated with senior leadership, internal and external stakeholders, NASA Centers, NASA Management Councils, the public, OMB, the Office of Science and Technology Policy (OSTP) and the National Space Council. An OMB Working Group also helped coordinate across the agencies to infuse best practices into the Strategic Plan.

The new Vision and Mission statements for NASA are as follows:

Vision
To discover and expand knowledge for the benefit of humanity.

Mission Statement
Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the Solar System and bring new knowledge and opportunities back to Earth. Support growth of the Nation's economy in space and aeronautics, increase understanding of the Universe and our place in it, work with industry to improve America's aerospace technologies, and advance American leadership.

The four themes are connected with four strategic goals and tied to 13 near-term strategic objectives, the majority of which are cross-cutting, and which support a number of strategic goals. General Lyles, noticing the thematic focus on Space, commented that he hoped that Aeronautics was not being overlooked in the themes, Aeronautics appears to be overlooked in the Strategic Plan, while it really is important. He added that Aeronautics does cross over into all four themes, although it is mentioned only under one theme (Develop). Mr. Borghese said that the net overall benefit of Aeronautics as an industry-enabling ability is worth $80B to the nation; no other government agency can make that statement. Asked about international collaborations, Mr. Walters said that in the body of the text, there are many references to both international collaborations and Aeronautics.

Mr. Hunter reviewed Agency Priority Goals (APGs): among these are JWST, Mars 2020, technology demonstrations on ISS, early Exploration missions, and Commercial Crew providers. General Lyles asked why there was no APG for Aeronautics. Mr. Walters said there had been a discussion about having LBFD called out as an APG, but he said it would indeed show up in later budget years. General Lyles stressed that ATM and UAS research is also absolutely critical and should be regarded as an APG. Mr. Walters noted that the heavy reporting requirements levied on APGs tended to limit their numbers. Dr. Ballhaus, speaking as a traditional advocate for Aeronautics, also acknowledged that some things must be

absolutely successful, such as JWST and Commercial Crew. Aeronautics is a $600M investment, while JWST is $8B; these are high-risk missions at which NASA must succeed. Mr. Borghese agreed, but stressed that while the funding is small by comparison, the success in Aeronautics, particularly in upgrading air traffic management systems, is very important for the new aviation industry and for the nation. Dr. Ballhaus felt that a compelling case should be made to make Aeronautics a much bigger program, as it underpins the defense industry, the balance of trade in the U.S., and air transportation; NASA should create programs that significantly move the needle.

Mr. Walters detailed the strategy performance framework, the content of which leads to annual performance indicators, with first-year reporting to take place in the third and fourth quarters. General Lyles asked how the Strategic Plan would be marketed. Mr. Walters explained that at NASA Headquarters, some of the rollout is just part of document alignment, but that the Agency has also identified Center "champions" for the Strategic Plan. Dr. Ballhaus asked how the Plan would be incorporated into individual performance plans and reporting to NASA program managers. Mr. Walters said that his team publishes the performance plan, along with the annual performance report, but that flow-down logistics would be a question for the Office of NASA Administrator.

Science Committee Report

Dr. Bradley Peterson, outgoing Chair of the Science Committee, gave his final presentation to the NAC. He noted that the Science Committee had met the previous week, and currently has two empty seats to be filled. Dr. Peterson began with significant science results. In Heliophysics, the Magnetospheric Multiscales (MMS) mission observed Kelvin Helmholz waves at the interface of the Earth's magnetic field, allowing inferences to be made about how the solar wind impacts the Earth's magnetopause. These tornado-like waves are vortices that drive solar wind particles into the magnetosphere. In Earth Science, data from Earth-observing instruments are contributing to the improvement of drought assessments. The Gravity Recovery and Climate Experiment (GRACE) satellite, in particular, is able to see mass concentrations that show water movement in the Earth's surface, enhancing the ability to monitor drought in both long- and short-term timescales. Other critical Earth-imaging satellites are Suomi National Polar-orbiting Partnership (NPP) and Terra 3. Earth-monitoring satellites have also been critical to disaster response, particularly during 2017's busy season that included major hurricanes, earthquakes, and wildfires. Mr. Borghese asked if there were any sensors that can predict drought, or weather patterns such as El Nino. Dr. Peterson said he knew there were indicators (e.g., sea-surface temperature) that could act as El Nino predictors, and that as models get more sophisticated, these predictions will improve. In Planetary, the Lunar Reconnaissance Orbiter (LRO) wide-angle camera identified titanium dioxide deposits on the Moon, often found in basalt, indicating volcanic activity in finer detail than previously possible. The Juno mission to Jupiter was the subject of an entire *Nature* edition, featuring spectacular images. Data looking at small perturbations in trajectory have provided better insight into Jupiter's interior. The gas planet rotates much like a solid body, even though its atmosphere is 1% of its total mass. By comparison, the Earth's atmosphere is one millionth of its total mass. In Astrophysics, data from Chandra provided new insights into an ultraluminous x-ray source (ULX) from M51. Bright objects tend to be very massive, and the Eddington limit keeps stars at about 100 solar masses. Any larger, and the stars would disintegrate. Most ULX sources turn out to be neutron stars, which are usually identified by pulsating, and this was found to be the case for M51's ULX source.

The Science Committee received a programmatic status on SMD missions, given by the SMD Associate Administrator, Dr. Thomas Zurbuchen, and found that all science areas were very well represented. SMD has a very active launch schedule this year. The Transiting Exoplanet Sky Survey (TESS) will be launched at the end of April 2018. Compared to the Kepler mission that stared at transiting stars, TESS will look at an area that is 400 times the area seen by Kepler; the viewing field is not as deep. TESS will pick up exoplanets that are around the nearest bright stars. Kepler found 3500 exoplanets; TESS will

probably identify fewer, but they will be closer. The Astrophysics Division (APD) Director, Dr. Paul Hertz, added that TESS will download 2 million stars and galaxies at 30-minute cadences for two years and will change its pointing orientation every month. TESS will look at both Northern and Southern hemispheres and will incidentally provide data about the local quasar population. There are four white-light cameras on TESS, each with a wide field of view. The non-cryogenic mission is measuring photometry and is not providing high-resolution images. Kepler was actually de-focused to avoid the saturation of its sensors.

Dr. Peterson noted that the Heliophysics Parker Solar Probe will launch in July 2018. It will travel to within 4 million miles of the Sun. It is the first mission to be named after a living scientist, Dr. Eugene Parker, who discovered the solar wind. JWST's components are now all together at Northrop Grumman, where it is undergoing its next thermal vacuum test. Dr. Peterson that he was institutionally conflicted with regard to JWST, and therefore would direct all NAC questions to Dr. Hertz, who explained that the primary factor in JWST's launch delay is the underestimation of the integration and testing (I&T) schedule. The sunshield, which is the size of a tennis court, takes months to deploy and test. Thus far, JWST has deployed and stowed the sunshield once, and must repeat this test once more. Dr. Zurbuchen has established an independent review board, chaired by Mr. Tom Young, to ensure and validate that all the appropriate tests can be done within the time remaining before launch.

The Science Committee received a briefing from the Joint Agency Satellite Division (JASD), which carries out reimbursable missions and launches satellites for the benefit of other agencies, the National Oceanic and Atmospheric Administration (NOAA) in particular. JASD is performing spectacularly well. The Joint Polar Satellite System-1 (JPSS-1) mission launched in November 2017 on the second to last Delta II rocket, and has already provided greatly improved imagery of the most recent California wildfires. GOES-S was launched earlier this month on an Atlas V rocket and will become known as GOES-17 under NOAA. GOES-R and S together provide a view of Earth every 15 minutes, in multiple bands (visible and non-visible). Dr. Peterson noted the output of an SMD Strategic Data Management Working Group, whose primary finding was that about half of new science results are based on archived data, highlighting the extremely valuable NASA archives. The Science Committee also held two working sessions on the output of the NAC Big Data Task Force (BDTF), which reported to the Science Committee and has been decommissioned. The Science Committee has made progress on formulating the BDTF final recommendations, which will be presented at the NAC's July 2018 meeting. The Science Committee agreed with most of the BDTF's findings and recommendations but had some differences in opinion on implementation. Mr. Borghese asked about some issues in the future of data analysis infrastructure. Dr. Peterson reported that BDTF had studied the use of server-side analytics and downloadable archives, concluding that data analysis should be handled by each SMD Division in ways appropriate to each discipline. General Lyles commented that someone has to keep an eye on Enterprise data. Dr. Peterson agreed, adding that communication across SMD Divisions will be key to this issue.

The Science Committee is also answering a charge on Research and Analysis (R&A) from the SMD Associate Administrator, to determine whether the current program supports high-risk, high-impact projects; the discipline committees are gathering data for final deliberations, which will also be delivered in July 2018. The Science Committee received an impressive briefing on SMD's efforts in promoting diversity and inclusion and was pleased by a proactive approach and the level of care and attention being shown to the effort. General Lyles asked if every aspect of diversity, such as ethnicity, skill set, and gender, were being viewed in a broad sense. Dr. Peterson reported that this was indeed the case. The Science Committee also presided over a Skype session with Dr. Tammy Jernigan, former ISS astronaut, that was broadcast to a local elementary school in Arlington, Virginia.

In general, the Science Committee had no findings to go forward, but mentioned one "attaboy" finding on JASD that would be directed to the SMD Associate Administrator. The proposed finding approved by the Council is provided below:

> *The Science Committee finds that the spacecraft launched through the Joint Agency Satellite - Division (JASD) program already have delivered tremendously valuable date that serves multiple stakeholders, and provides broad societal benefits, one of the major goals of NASA. Some of the initial instrumentation on GOES-S is potentially game-changing, such as the Geostationary Lightning Mapper (GLM), allowing weather systems to be observed at excellent resolution. These capabilities allow us to move forward and incorporate advances into new model development, as only a minimal amount of interpolation is needed (e.g., ocean observations are being resolved at the needed time and space scales). The Science Committee appreciates NASA's strong partnership with the National Oceanic and Atmospheric Administration (NOAA) on these efforts. In this time of extreme weather, these capabilities allow the prediction of a host of weather events, as well as their consequences.*

Mr. Ballhaus asked if the 70% confidence level in cost estimation was still being applied to SMD missions. Dr. Hertz said that since SMD started the policy six years ago, as a portfolio, SMD is delivering 3% under the cost commitment, and under the schedule commitment. Mr. Bowersox noted that the bigger multi-decadal programs might do better under a different management directive. Dr. Ballhaus felt that a very risky program might need a 90% confidence level.

A final finding regarding workforce diversity was proposed by the Science Committee for the SMD Associate Administrator, and was approved by the Council as follows:

> *The Science Committee finds that NASA is taking proactive steps to make the workforce more inclusive and equitable, and is undertaking efforts to better quantify problems in diversity and inclusion.*

General Lyles and the entire Council expressed their deep appreciation for Dr. Peterson for his exceptional service as a member of the Council, and as Chair of the Science Committee.

NASA Space Technology Mission Directorate Update

Mr. James Reuter, STMD Acting Associate Administrator, gave an update on the directorate. He noted that Mr. Steve Jurcyzk, former STMD Associate Administrator, had recently been named as NASA Acting Associate Administrator. Mr. Reuter discussed the implications of the FY 2019 integration plan of STMD into the new Exploration and Research Technology (ER&T) Directorate. It would transition from a cross-cutting Mission Directorate that treats SMD and HEOMD equally, to a directorate that only considers Science if Exploration is a goal. One example is the work it has been doing on a coronagraph to be used in WFIRST. STMD always looks for a "ride" to infuse these technologies. Appropriations for the Research and Technology line item have slightly increased, but the increase comes with caveats: there are five Congressional directives governing this line item, including the Restore-L mission satellite-servicing mission. The new directorate would take the $130M appropriation and bring $45M to use a public/private partnership to enact the mission. Its Key Decision Point-C (KDP-C) milestone is coming up. To promote public-private partnerships, STMD uses the "Tipping Point" program to solicit in-space rides; participants have to provide 25% of the funds and a business plan. With the FY 2019 budget, the directorate has a budget for a flight demonstration for one of these selections. Another Congressional directive is nuclear thermal propulsion, which is focused on the fuel element, engine work, and some cost assessments for risk mitigation. Based on last year's direction, STMD spent $35M on the topic. This year, there is a $40M gap going forward; STMD is still having the discussion with the commercial entity involved.

STMD is supporting the NASA Exploration Campaign and is soliciting proposals for a small commercial lander, and is also developing the unit for the Gateway SEP unit. Under the new ER&T line, prior work on habitation will be transferred and implemented in 2019. Environmental and life support technologies are already covered in HEOMD. The coronagraph work will be moved to SMD as the integration effort goes forward. High-performance space flight computer work, which includes contributions from other agencies, will be used in technology demonstrations for precision landing. Technology Readiness Levels (TRLs) for these projects typically span TRLs 1 through 7. ER&T will also do capability demonstrations, such as deep space optical communications for the Psyche mission. There is a wide range of s companies doing habitation studies; the next step in this area is a Request for Proposals (RFP). STMD helps monitor these solicitation approaches to see where it can help. There is also ongoing work in materials for radiation protection. Mr. Borghese asked if ER&T intended to space-certify existing multicore processors. Mr. Reuter said he would follow up on this question.

Key technology areas in ER&T are advanced environmental control and life support systems, *in-situ* resource utilization (ISRU), for which there is a next step BAA out for both lunar and Mars applications; power and propulsion; advanced communications, navigation and avionics; in-space manufacturing and on-orbit assembly; advanced materials; EDL; autonomous operations; and human operations in various space environments. These technologies will be funded at $3M a year for 5 years; eventually increasing to $6M per year. Thermal Protection Systems (TPS) work for missions to multiple planets are also in work.

FY 2018 accomplishments include the development of two CubeSats: Integrated Solar Array and Reflectarray Antenna (ISARA), a solar array integrated with an antenna, which is working well; and CEPOD, an operations and docking unit that should launch later this year. Station Explorer for X-ray Timing and Navigation Technology (SEXTANT) is an instrument that will use pulsar stars as a galactic navigation system. A Preliminary Design Review (PDR) has been completed on thrusters for PPE. The Kilopower project, a one-kilowatt ground demonstration that is being developed under a cooperative effort with the Department of Energy (DOE), has begun testing; the goal is to scale it to ten kilowatts. Deep Space Optical Communications, a laser communication system, has entered the I&T phase and will flying in 2019, coordinating with HEOMD's Space Communications and Navigation (SCaN), and the AFRL (providing launch and encryption). STMD held a SBIR/STTR Industry Day that attracted 450 participants, and successfully flew a navigation Doppler lidar precision landing technology. Centennial Challenges attracted winning experiments such as 3D-printed habitats using regolith, binders, and water. A single individual succeeded in the Space Robotics Challenge, without a flaw, in developing an autonomous response to a simulated situation. Asked if he anticipated continuing progress in these areas as the directorate structure changes, Mr. Reuter said he would "run until apprehended." He felt that the NASA Innovative Advanced Concepts (NIAC) program would continue, but that Regional Economic Development would not continue.

FY 2019 milestones include producing an ISRU unit, Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), for Mars 2020, to be delivered in November for integration; CubeSat activities; and delivering a Space Craft Oxygen Recovery unit to HEO. Extreme Environment Solar Power will be delivering test articles in September 2019; and eCryo will be completing a ground demonstration. STMD is doing some composite work with the Space Launch System (SLS) for joining technologies; and is working on both the MSL EDL Instrument (MEDLI) and Terrain Relative Navigation for Mars 2020 (due February 2019). Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID), a developing technology demonstration that will fly as secondary payload, will hold its KDP-C and Critical Design Review (CDR) in 2019; it has potential commercial applications. Astrobee, a free flying cube-shaped robot, will be demonstrated at ISS.

The ER&T program structure will retain all the major STMD programs except Regional Economic Development. The FY 2019 budget for Technology Maturation has some new content. Early Stage Innovation (TRL 1 through 4) has been increased to $72M. A pilot program has been added back in for Early Career proposers; two per year have been budgeted. The goal is to have every center with one in work.

Technology Maturation (Game Changing Development) has seen some minor changes. Space observatory systems will go to SMD, but ER&T will continue to work with SMD where it can be helpful. All current items will go to completion. Tipping Point technologies will cover several topics from 2016 through 2019; five to 10 awards are anticipated in 2018. DARPA will be involved in setting standards for in-space assembly, and robotics. General Lyles noted that DARPA is setting up a new Technology Maturation office. Mr. Reuter agreed to reach out to them.

Technology, Innovation and Engineering Committee Report

Dr. William Ballhaus gave a report on the Technology, Innovation and Engineering Committee's latest activities. At its March 26, 2018, meeting, TI&E received an STMD update and toured projects at the NASA Goddard Space Flight Center. Dr. Ballhaus described working with STMD as" terrific" and said he believed Mr. Jurczyk was the right person to deal with the upcoming re-organization. The Committee discussed x-ray communications, laser communications, the SEXTANT mission, and the Restore-L launch. Regarding budget challenges, the Committee believes that STMD has been disadvantaged by a lack-of-urgency argument due to a lack of an overarching exploration architecture and plan. The Presidential Space Policy Directive 1 has changed this, and now provides a near-term destination for a detailed program plan; this will pull the technologies along.

Dr. Ballhaus reviewed past Committee output that had recognized NASA's grand missions as technology-enabled, which in turn demonstrated U.S .and NASA technical leadership. Moreover, the Committee had found that this leadership is a "soft power" that other nations want to emulate. In July and November 2016, the Committee reiterated these observations, and in 2012 had posed questions to the NASA Administrator regarding what sort of funding should NASA "fence off" for technology development. Mr. Lightfoot led a study across the agency to answer the last question. The study could not find any accounting that could reveal exactly what percentage was devoted to technology. The Committee concluded in 2012 that the Constellation "ate" the Technology program. With the creation of STMD, however, the Committee was encouraged that NASA had selected an effective way to support healthy technology development. Thus, the Committee is concerned about STMD's reorganization. Dr. Ballhaus brought forth a proposed Committee finding on this concern. Following Council deliberation, the following finding was approved for the NASA Administrator:

> *The Council finds that NASA's major missions have been enabled by technology investment over a number of years. Previous experience with housing "seed corn" and crosscutting technologies in development mission directorates produced unfortunate results:*
>
> • *Drastic reductions in those technology budgets.*
> • *Alienation of university connections – the major source of human capital for NASA and its contractors.*
>
> *The Space Technology Mission Directorate (STMD) was established to reverse these outcomes and has produced a robust technology portfolio with university and industry partnerships.*

The Committee observed in 2015 that NASA had successfully mended its ties with universities, met with fellows, and awarded many Space Technology Research Grants (STRGs). Asked if there had been any historically black colleges and universities (HBCUs) on this list of STRGs, Mr. Reuter said STMD is addressing these issues and will look for HBCUs during the selection period. Dr. Ballhaus noted that in 2016, the Committee .observed NASA had done an excellent job with STMD accomplishments in re-engaging academe and rekindling students' interest in NASA. Dr. Penina Axelrad observed that technology fellowships have had a huge impact and have resulted in many students working at NASA; her institution regularly had the best students applying for positions. Dr. Elisabeth Paté-Cornell remarked that at Stanford University, the Jet Propulsion Laboratory (JPL) has been instrumental in focusing students' attention on the U.S. space program. General Lyles encouraged STMD to interact with HBCUs that are closer by, at Howard University in Washington, DC, for instance.

Based on the Committee finding on this topic, the Council drafted and approved a recommendation on the proposed organization options to promote technology investment. It reads as follows:

> *The Council recommends that the NASA Administrator task the Acting Associate Administrator to develop and present to the Council mechanisms and/or a hybrid organizational option that promotes appropriate levels of investment in early and mid-stage technology development and University grants and fellowships. This includes defining metrics to assess effectiveness.*

Council Discussion

With regard to priority topic areas for 2018, Dr. Paté-Cornell suggested a more thorough discussion of international collaborations, beyond ISS, and addressing risks, redundancies, and other options. She also wanted to learn more about what other space agencies are planning, across the board. Dr. Peterson recommended gathering more data on SLS and Orion, and where ESA is involved. Mr. Bowersox recommended that Council members read the report from the ISECG meeting in California.

The Council tentatively agreed that the next Council meeting would take place at NASA Ames Research Center in July 2018, during the week of July 9 or July 23, or at the end of August 2018. The final meeting would take place at NASA Kennedy Space Center, and was tentatively scheduled for December 6-7, 2018.

Council Wrap-Up and Acknowledgments

General Lyles concluded the Council with a roundtable discussion. He raised the idea of a Council teleconference with the new NASA Administrator as soon as feasible after appointment, in order to provide feedback. Dr. Peterson reiterated his deep concern about the fate of technology development, and added that it had been an honor and privilege to serve on the Council. Dr. Paté-Cornell noted her continuing concern about the cybersecurity risk to missions. Mr. Tony Cole vowed to provide support as soon as possible re: cybersecurity. Dr. Sanders suggested, given all the discussion about aviation, that the Council propose a recommendation to the new Administrator to raise the visibility of Aeronautics. Mr. Bowersox thanked the Council for another great meeting, and expressed his appreciation for the departing Dr. Peterson. Dr. Ballhaus echoed the comments of his colleagues. Mr. Borghese said he had learned a great deal, and thanked General Lyles for his support of Aeronautics. He praised Mr. Lightfoot in leading NASA for 18 months, helping the NASA team to continue to meet its commitments in all areas of NASA.

General Lyles adjourned the Council meeting at 3:52 pm.

APPENDIX A

AGENDA

NASA ADVISORY COUNCIL

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

March 28-29, 2018

PUBLIC MEETING

Wednesday, March 28, 2018

1:00 pm	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council NASA
1:05 pm	Welcome and Introductions	General Lester Lyles (USAF, Ret) Chair, NASA Advisory Council
1:20 pm	NASA Exploration Update	Mr. William Gerstenmaier Associate Administrator HEOMD
2:20 pm	Human Exploration and Operations Committee Report	Mr. Kenneth Bowersox, Chair
3:00 pm	Aeronautics Committee Report	Mr. John Borghese, Chair
3:45 pm	Ad Hoc Task Force on STEM Education	Dr. Aimee Kennedy, Chair
4:30 pm	Remarks by NASA Acting Administrator NASA Acting Administrator	Mr. Robert M. Lightfoot, Jr.
5:00 pm	Adjourn	

Thursday, March 29, 2018

9:00 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council NASA
9:02 am	Opening Remarks	General Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council

9:20 am	Public Input	
9:30 am	President's FY 2019 Proposed Budget for NASA	Mr. Andrew Hunter Deputy Chief Financial Officer NASA
10:30 am	NASA 2018 Strategic Plan	Mr. David C. Walters Office of the Chief Financial Officer NASA
11:15 am	Science Committee Report	Dr. Bradley Peterson, Chair
1:00 pm	NASA Space Technology Mission Directorate Update	Mr. James Reuter Acting Associate Administrator Space Technology Mission Directorate NASA
2:00 pm	Technology, Innovation and Engineering Committee Report	Dr. William Ballhaus, Chair
2:45 pm	Council Discussion - 2018 Priority Topic Areas - 2018 Meeting Schedule	All
3:45 pm	Council Final Wrap-Up and Acknowledgments	All
4:00 pm	Adjourn	

APPENDIX B

COUNCIL MEMBERSHIP

NASA ADVISORY COUNCIL
Membership Roster

Position	Council Members
Chair – NASA Advisory Council	**General Lester Lyles,** *USAF (Ret.)*
Chair – Aeronautics Committee	**Mr. John Borghese,** *Rockwell Collins ATC*
Chair – Human Exploration and Operations Committee	**Mr. Kenneth Bowersox,** *U.S. Naval Aviator (Ret.); Former NASA Astronaut*
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	**Dr. Elisabeth Paté-Cornell,** *Professor and Founding Chair, Department of Management Science and Engineering, Stanford University*
Member at Large	**William B. (Tony) Cole,** *FireEye and Global Government CTO*
Member at Large	**Mr. Miles O'Brien,** *Independent Journalist*

Ex Officio Members	**Dr. Alan H. Epstein**, *Chair, Aeronautics and Space Engineering Board, National Academy of Engineering* **Dr. Fiona A. Harrison,** *Chair, Space Studies Board, National Academy of Sciences*

APPENDIX C

MEETING ATTENDEES

NASA Advisory Council Members:	
General Lester L. Lyles, *Chair*	U.S. Air Force (Ret.)
Dr. Penina Axelrad	University of Colorado, Boulder
Mr. Kenneth Bowersox	U.S. Navy (Ret.)
Dr. William Ballhaus	The Aerospace Corporation (Ret.)
Dr. Tony Cole	FireEye
Mr. John Borghese	Rockwell-Collins ATC
Dr. Alan H. Epstein, *Ex Officio*	Chair, Aeronautics and Space Engineering Board
Mr. N. Wayne Hale	Special Aerospace Services, Former NASA (Ret.)
Dr. Aimee Kennedy	Battelle
Dr. Elisabeth Paté-Cornell	Stanford University
Dr. Bradley Peterson	Ohio State University
Dr. Patricia Sanders	Chair, NASA Aerospace Safety Advisory Panel
Ms. P. Diane Rausch, *Executive Director*	NASA Headquarters
NASA Attendees:	
DaMara Belson	NASA Headquarters
Kris Brown	NASA Headquarters
Christie Cox	NASA Headquarters
Elaine Denning	NASA Headquarters
Jamie Favors	NASA Headquarters
T. Jens Feeley	NASA Headquarters
Merrilee Fellows	NASA Headquarters
Chris Fitzsimonds	NASA Headquarters
Robyn Gatens	NASA Headquarters
Beverly Girten	NASA Headquarters
William Gerstenmaier	NASA Headquarters
Mike Green	NASA Headquarters
Paul Hertz	NASA Headquarters
Andrew Hunter	NASA Headquarters
John Karcz	NASA Headquarters
Mike Kincaid	NASA Headquarters
Marla King	NASA Headquarters
Augustine Manke	NASA Headquarters
Meredith McKay	NASA Headquarters
Toni Mumford	NASA Headquarters
Michael New	NASA Headquarters
Robert Lightfoot	NASA Headquarters
Krista Paquin	NASA Headquarters
Michael Romano	NASA Headquarters
James Reuter	NASA Headquarters
Laura Shaw	NASA Headquarters
Steve Shih	NASA Headquarters
Bette Siegel	NASA Headquarters
Ray Taylor	NASA Headquarters
Douglas Terrier	NASA Headquarters
Michael New	NASA Headquarters
David Walters	NASA Headquarters
Cheryl Warner	NASA Headquarters
Mike Witt	NASA Headquarters

Renee Wynn	NASA Headquarters
Thomas Zurbuchen	NASA Headquarters

Other Attendees:

Francesco Bordi	Aerospace
Mary Floyd	Zantech IT, Inc.
Kate Kronmiller	Jacobs
Joan Zimmermann	Zantech IT, Inc.

WebEx Attendees (virtual):

Gale Allen, NASA
Darrell Branscome, NASA Consultant
Margarite Broadwell, NASA
Stephen Clark, Space Flight Now
Angela Clark-Williams, Zantech IT
Al Conby, NASA
Alberto Conte, Northrop Grumman
Diane Detroy, NASA
Rob Evans, Battelle
Jeff Foust, Space News
Chris Gilbert, VE Consult
Ellen Grant, NASA HQ
David Gump, Deep Space Industries
Kathryn Hambleton, NASA
Kyle Herring, NASA
David Hitt, ASRC Federal
Dave Huntsman, NASA
Daniel Huot, NASA
Roosevelt Johnson, NASA
Bill Kahle, Public
Theodore Kronmiller, Law Office
Richard McKinney, News Space Consultant
Gene Mikulka, Talking Space
Susan Minor, NASA
Marian Norris, NASA
Bill Peterson
Jose Ramos, GAO
Xaivien Raymond, NASA
Michelle Rodrigues, SRI International
Marc Seibert, NASA Contractor
Mary Sladek, NASA HQ
Elizabeth Smith, NASA
Marcia Smith, Space Policy Online.com
Dee Solage, NASA
Mark Sonner, Defense Daily
Dave Stietz, NASA
Rob Landis, NASA
Van Troy, UMB
Ashley Wilkins, Astronomical Society

APPENDIX D

LIST OF PRESENTATION MATERIAL

1) NASA Exploration Update – Mr. William Gerstenmaier
2) Human Exploration and Operations Committee Report – Mr. Kenneth Bowersox
3) Aeronautics Committee Report – Mr. John Borghese
4) Ad Hoc Task Force on STEM Education Report – Dr. Aimee Kennedy
5) President's FY2019 Proposed Budget – Mr. Andrew Hunter
6) NASA 2018 Strategic Plan – Mr. David Walters
7) Science Committee Report – Dr. Bradley Peterson
8) NASA Science and Technology Mission Directorate Update – Mr. James Reuter
9) Technology, Innovation and Engineering Committee Report – Dr. William Ballhaus