

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

NASA ADVISORY COUNCIL

**NASA Kennedy Space Center
Florida**

October 31 - November 1, 2019

MEETING MINUTES

**P. Diane Rausch
Executive Director**

**Lester L. Lyles
Chair**

NASA ADVISORY COUNCIL

**NASA Kennedy Space Center
Florida**

October 31 – November 1, 2019

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*Meeting Report prepared by
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Call to Order/Announcements

General Lester Lyles, Chair of the NASA Advisory Council (NAC, or Council) introduced Ms. P. Diane Rausch, Executive Director of the NAC. She officially called the meeting to order, and made administrative remarks pertaining to the Federal Advisory Committee Act (FACA) rules that govern the NAC.

Welcome and Introduction

General Lyles welcomed NAC members and meeting attendees to the Fall 2019 meeting of the NAC. Introductions were made around the table. General Lyles introduced the Director of NASA Kennedy Space Center (KSC), Mr. Robert Cabana, and expressed his appreciation for the outstanding, extensive tour of KSC the NAC had received the previous day. General Lyles described it as an opportunity for the NAC to see the very best the country can offer in space technology and science.

Welcome to NASA Kennedy Space Center

Mr. Robert Cabana, KSC Director, provided a briefing on Center activities, which is currently in the midst of great change. KSC is completing the transition from a single government entity to a diverse, multi-use spaceport. The Space Launch System (SLS) and Orion are being prepared to share a launch pad. KSC has agreements in place with SpaceX, and thus far has had 19 successful launches with the company. The former Shuttle landing facility is being commercialized for use by Space Florida. The Orbital Processing Facility is now being used by Boeing for the development of its Starliner rocket. KSC is also housing the Air Force X-37 test vehicle, which has recently returned to Earth after a lengthy test flight. Lockheed Martin is building the Orion Spacecraft at KSC in collaboration with the University of Florida. Exploration Park is being leased to Space Florida, and is also where Blue Origin now resides. KSC also hosts Firefly Aerospace, another emerging space entity. At the end of the Shuttle era, KSC had 15,000 people in its work force, and within two years that number was halved. Today there are 7800 NASA employees on the KSC campus, both civil servants and contractors. Space X has 500 employees at present, and Boeing and Lockheed Martin continue to bring on more staff.

The SpaceX Demo-1 test flight of the Dragon 2 crew vehicle went flawlessly. The refurbished Mobile Launcher has been brought out to Pad 39B to undergo verification and validation (V&V) in preparation for SLS operations. The last mission launched from the Center was the Heliophysics mission, Ionospheric Connection Explorer (ICON), which deployed from a Pegasus carried on an L-1011 aircraft. A NASA collaboration with the European Space Agency (ESA), Solar Orbiter (SO), is set to launch in February 2020, and the Mars 2020 rover in July 2020. Half of the Commercial Crew Program (CCP) is housed at KSC, and the other half at Johnson Space Center (JSC). Both SpaceX and Boeing are moving toward the first uncrewed test flights of their crew vehicles to the International Space Station (ISS) in late

2019. SpaceX is getting ready to test its Dragon capsule in-flight abort test, while Boeing is planning a flight abort test at White Sands, New Mexico, for its Starliner launch vehicle.

Mr. Cabana addressed the Artemis Program, noting that its “Moon Before Mars” theme was absolutely appropriate for proving the necessary exploration systems close to home. ISS has been an outstanding test bed for keeping humans alive in space and has been helping NASA to learn more about operating in a longer-term manner on the lunar surface. It is critical to learn how to operate in deep space beyond Earth. Gateway will be the first step in creating a sustainable presence in low-Earth orbit (LEO), and NASA is now in an accelerated program to get to the Moon, via Gateway, by 2024 instead of 2028. There are contracts in place for the Gateway Power Propulsion Element (PPE) and the Habitation and Logistics Outpost (HALO), and plans to award the Human Landing System (HLS) contract in the near future. Artemis I, formerly Exploration Mission 1 (EM-1), will be the first flight test of Orion. It is now getting ready to be shipped to the Plum Brook Station in Ohio for environmental testing and will return in Spring 2020 for integration and stacking on SLS. Artemis II will be the first flight of crew to the Moon aboard SLS and Orion. Artemis III will be the first crewed flight to the lunar surface. With proper funding, Mr. Cabana was confident that NASA would be able to make the 2024 target date.

Studies indicate that approximately 40 metric tons of equipment will have to be placed on the surface of Mars, and on one flight, to support an extended human sortie. To learn to do this, Artemis will pave the way for sustainable presence on Mars by developing space technology for 2024 and beyond. Exploration Ground Systems (EGS) are now being tested on Pad 39B, ahead of the launch of Artemis I. The Core Stage Pathfinder for SLS is now housed in KSC’s Vehicle Assembly Building (VAB). SLS uses four Shuttle engines and five solid rocket boosters; its Core Stage is slated to enter Green Run testing around early 2020.

The Center is preparing to receive the SLS Enhanced Upper Stage (EUS), and is building a second Mobile Launcher, while also adding three adaptable platforms to the VAB. The new Mobile Launcher is complete and was originally designed for the Constellation rocket (single-stick solid), thus it did require some modifications to support SLS. It is 10.5 million pounds and 355 feet tall. The Crawler Transporter, built in the 1960s has also been completely re-done. Launch Pad 39B has been similarly refurbished and stands ready to support multiple launch events. A 1.2-million gallon hydrogen sphere, the largest in the world, was recently added to the launch complex, and the flame trench has also been re-done.

Landing and Recovery operations are well underway. The Orion Ascent Abort-2 flight test was successfully completed on July 2, 2019. The Firing and Launch Control rooms are being prepared, and the first female launch director is already running launch simulations. These tests and simulations are very valuable exercises, and to their purpose of uncovering issues, are running as expected.

The Launch Services Program continues to do an outstanding job. The Exploration Research and Technology programs at KSC are carrying out intensive studies in space plant biology, important for both feeding and providing psychological comfort to future exploration crews. KSC is the only NASA Center to win a Federal Laboratory Consortium (FLC) interagency award for its ground-breaking efforts in technology.

The KSC Roadmap contains planning for 65 launches in the next five years, a manifest worth a billion dollars, excluding commercial and Department of Defense (DOD) launches. Mr. Cabana predicted that the next 50 years of space exploration would be even more exciting than the last 50, and felt that NASA’s mission was critically meaningful for humanity. He added that NASA has the right people in the right place, but it will need the right resources and budget to be successful in these new exploration endeavors.

The Council took time to ask questions of Mr. Cabana. Dr. Meenakshi Wadhwa, Chair of the NAC Science Committee, said that KSC's first female flight director, Charlie Blackwell-Thompson, had spoken eloquently about the need for training the future workforce. Mr. Cabana noted that KSC now carries a requirement to hire 50% freshouts, as the average age at KSC is now 47 years. He said that NASA is still a draw for young people, and the freshouts are very talented. Interns are writing code for the Spaceport Command and Control System, as just one example of their contribution. While it is an exciting time for new hires, it is still challenging to find qualified engineers. However, Mr. Cabana said he was not worried about the future and had faith he would be able to hire the necessary talent. He noted he had to find talent among the contractors once in a while, but that he was still meeting the freshout requirement. Mr. John Borghese, Chair of the NAC Aeronautics Committee, asked if KSC were preparing for the effects of climate change and the increased risk of strong hurricanes. Mr. Cabana said that KSC had just completed a multi-million dollar dune restoration project, which stood up well to recent storm surge events, and that KSC continues to look at protecting the range. All new buildings are built to code for withstanding hurricanes. The VAB stood up well to winds of 118 knots during the last major storm. The facilities are upgraded and hardened with each hurricane. General Lyles finalized the discussion by commending Mr. Cabana on his receipt of the Service to America Medal, a richly deserved honor.

Remarks by NASA Deputy Administrator

Mr. James Morhard, NASA Deputy Administrator, offered remarks, beginning with the story of how he had been inspired by a childhood encounter with Astronaut John Glenn, and how Mr. Glenn's honesty, kindness, and sharp memory had served him very well both in space and in the U.S. Senate. Mr. Morhard commented that, just like Mr. Glenn's first orbits around the Earth, if the U.S. is not flying, it is not exploring, and it is not finding new science and technology. The U.S. is entering a transformative time in space. Thanks to Space Policy Directive 1 (SPD-1), NASA is working toward five strategic goals: to transition LEO to commercial operations; lead the way in lunar surface operations; foster scientific discovery; return U.S. astronauts to the lunar surface; and demonstrate on the Moon capabilities for Mars and beyond. The strategy to achieve these goals now exists, starting with Artemis and continuing with a forward focus to discovery.

New missions such as the Volatiles Investigating Polar Exploration Rover (VIPER) will map lunar water distribution, much as water resource mapping is done on Earth. The Lunar Surface Innovation Initiative (LSII), a project under the Space Technology Mission Directorate (STMD), will develop systems to provide lunar surface power and look for ways to address the challenges of extreme environments, advance technologies for dust mitigation, excavation and construction, and develop in-situ resource utilization (ISRU) techniques. STMD is looking for breakthrough technologies that might lead to sustainable mining operations on bodies in space. NASA expects to see capital formation where it finds technology breakthroughs, however, the long-term goal of SPD-1 is to get to Mars.

Complex organic molecules are now known to exist on Mars, and it is believed that 12 kilometers beneath the Martian surface there is water, and potentially, life. Getting humans to the surface of Mars is a logistics effort larger than has ever been attempted. The primary objective under SPD-1 is to prove out exploration systems to support humans in space. There were 23 precursor missions to the Moon. NASA is now focusing on precursor missions that will get humans to Mars. The effort will require that NASA establish an alliance of international and commercial partners, an approach which will facilitate ongoing human deep space exploration and development. Competition is expected to drive down the cost of the long-term exploration effort. The Moon is the proving ground: what NASA is doing there must be replicated on Mars. The system architecture will be adjusted as new data are discovered, allowing more commercial opportunities to open up. NASA wants to use the Commercial Lunar Payload Services (CLPS) as much as possible, as a new way of exploring science. If the ability to mine resources on the

Moon is proven viable, then it can be done over and over. Humans could end up to going to different planets for different resources. The U.S. wants to build on its commercial market in LEO, and expand the market to the Moon and beyond. The approach takes advantage of continuing research at Mars, and part of the Artemis program involves expanding the coalition to include new strategic partners. SLS will send as many as four astronauts to Gateway and then the lunar surface, as NASA builds some of the most sophisticated equipment, along with ESA. Mr. Morhard credited the White House for supporting innovative ways to reach the Moon and prepare the way for Mars.

Mr. Morhard noted that Homer called Artemis, the “torch bringer.” Similarly, the Gateway is expected to evolve to include multiple modules from multiple partners. Gateway is not ISS; if ISS is a Marriott hotel, then Gateway is a pup tent by comparison. Canada has committed to Gateway, as has Japan. The space exploration community is growing. NASA met with 26 different countries last week to discuss the many possibilities of cooperation. It is not yet known whether humans can reside for long periods on either Mars or the Moon. The most fragile system in question is the human, particularly in the living body’s susceptibility to radiation damage. Living in microgravity interferes with sleep, contributes to bone and muscle loss, and poses challenges for creating and maintaining sustainable food sources. Food is a big issue – what happens if there is a crop failure in space? To advance the necessary technologies, NASA will continue to leverage the skills and interests of the international community, and scientists. The James Webb Space Telescope (JWST) will also help us peer beyond the Solar System. NASA is at the beginning of a journey. Half the people living in the U.S. today are too young to have witnessed the Apollo 11 mission and Moon landing in July 1969. Mr. Morhard hoped his children and grandchildren would be the children of Artemis, as he himself was a child of Apollo. NASA must be at the forefront of the effort, because exploration is a fundamental trait of the human species, and because the U.S. seeks to maintain its values of freedom and to better the condition of all peoples.

General Lyles asked Mr. Morhard if any concerns had been aired about Artemis at the previous week’s International Astronautical Congress (IAC). Mr. Morhard reported that the tone had changed throughout the week. At first, he had fielded questions about whether NASA was committed to the effort. By the end of the week, Mr. Morhard believed that NASA Administrator Bridenstine had successfully communicated the message. He noted however that every country has its own funding issues. The Exploration initiative will require a fragile choreography, and NASA must have the right people on the critical path. Dr. Wadhwa asked how, with the rapid changes in Exploration personnel and the newly aggressive schedule, NASA would ensure that science is not getting lost in the process. Mr. Morhard pointed out that NASA was founded in order to expand knowledge to help humankind. The Agency is working hard to make sure the Human Exploration and Operations Mission Directorate (HEOMD) is more integrated with the Science Mission Directorate (SMD) to support and promote science and exploration. The two subjects are inherently interrelated. Mr. Borghese commented that the Aeronautics Research Mission Directorate (ARMD) has been leading a revolution in unmanned aviation, supersonics, and electric propulsion for aircraft, and asked how NASA plans to maintain its cutting edge in these areas. Mr. Morhard noted that he had just seen ARMD’s X-57 all-electric aircraft, and that Europe is focused on zero carbon emissions, representing a large market. NASA’s Low Boom Flight Demonstrator could help to reintroduce supersonic air travel. Aeronautics is focused on safety, cost and schedule, and is doing very well. NASA Administrator Bridenstine is a former naval aviator, and he spends a lot of time with the Aeronautics program. General Lyles commented that Artemis begs for a whole-of-government approach, and asked if the formation of a “Deputy’s group” could contribute to this effort. Mr. Morhard said that such a group was a good idea, reminiscent of the Strategic Defense Initiative, but a much wider effort. He appreciated the suggestion and said he would try to get such a group under way.

NASA Human Exploration Update

Mr. Kenneth Bowersox, Acting Associate Administrator of HEOMD, briefed the NAC, noting that a new Associate Administrator, Mr. Douglas Loverro, has been named and would be stepping into the role shortly. He reviewed the principles of SPD-1, with an emphasis on an eventual Mars mission. It will be necessary to be able to sustain life for up to three years on Mars expeditions, and to do this, essential equipment and sufficient food resources must be placed on Mars ahead of time. Solar-electric propulsion (SEP), which will likely be the means of transport to Mars, will be demonstrated on the PPE at the Gateway. SEP must be super-reliable and must be proven out well before using it for Mars. NASA expects to use SEP in the earliest missions. There are many hazards associated with deep space travel that must also be dealt with: radiation, isolation and confinement for long periods, great distances from Earth, the effects of microgravity, and the challenges of a closed environment.

Mission needs drive the eventual design of each mission, and challenges are different with each destination. Some preliminary work will be best done in LEO, some on the lunar surface, but some work will have to be done at Mars. NASA is developing enhanced life support systems, which will continue at Gateway and on the lunar surface, and finally at Mars. The cornerstone of proving out these systems is ISS, which was a technological challenge at the beginning, but it was also challenge to grow the partnerships with internationals and commercials to support ISS. Over the last 20 years, NASA has created interoperability standards, with the help of a website, and the Agency continues to expand and evolve the ISS agreements to get out to the Moon and Mars. The interoperability standards have been developed and agreed upon by most participants, and every few years, the standards will be revisited as necessary. There are continuous cargo and crew operations on ISS, which includes participation of commercial and international partners. NASA is now looking to develop a commercial “ecosystem” in LEO, starting with a commercial port on ISS, and possibly a free flyer, with the end goal of eventually stimulating demand on Earth for an LEO market.

Mr. Bowersox reviewed the Artemis I phase of the path to Moon, which is focused on CLPS science landers and robotic landers, and the development of the Orion vehicle. Asked about the development of the VIPER mission, Mr. Bowersox indicated that VIPER would be one of the payloads for a medium/large cargo CLPS lander. Another Artemis I priority is to develop a heat shield, and also to test systems. Artemis II will be the first crewed lunar orbital mission with on-board life support systems; it will be a one-orbit mission, with a free return trajectory like Apollo 8. Artemis III will have the first rendezvous with Gateway, involving more complex orbital mechanics, and more like the rendezvous expected to be needed at Mars. Senator Bill Nelson asked: what is the value of the near-rectilinear halo orbit (NRHO)? Mr. Bowersox noted that NRHO is a stable orbit that will allow access to multiple sites on the Moon, in particular the lunar poles, which of are principal interest to the Exploration and Science programs. Another advantage of the NRHO is that it always facing Earth, allowing uninterrupted communications. Mr. Borghese noted that NASA needs to complete SLS, Orion, Gateway, and a landing system. He asked, what is the critical path to get to the Moon by 2024, besides funding? Mr. Bowersox responded that the key item to get done is the Human Landing System (HLS), and the first part of that task is to get a procurement mechanism in place.

The Exploration program has made excellent progress in getting crew to cis-lunar space. The SLS core stage is done, and engines are going in, and are ready for shipment to NASA Stennis Space Center. Boosters are ready to ship. Much smoother progress is being made on Artemis II, thanks to fewer first-time build issues. For Artemis III, a contract vehicle is in place to procure long-lead items for 2024. Orion is stacked at the Cape, and will ship to Plum Brook Station soon for testing, and will return in early 2020 for stacking at KSC. The Gateway will give NASA a strategic presence around the Moon, and will pass over every part of the Moon over a month’s time. The initial configuration of Gateway will focus on the minimum systems needed to support a 2024 landing; the HALO module will provide space for crew

materials, and will provide the ability to move critical supplies to the lander. The intent is to carry mass to Gateway via cargo vehicles and store it there. Eventually Gateway will host an international habitat, and there are already plans to send science experiments to Gateway. The current plan is to send two crew members to Gateway, not four, and science experiments will be included with the early missions. A federated board will work across SMD, STMD and HEOMD to coordinate work at the Moon.

A Human Landing System solicitation is now open after a NEXTStep Broad Area Announcement (BAA), and NASA is looking forward to receiving innovative concepts from industry. Proposals are expected in early November 2019, which will then be evaluated over a month's time. A minimum of three providers will be selected, and then downselected to two over the next year. A total of \$1B of the \$1.6B budget augmentation is intended for lander development. The intent is to fund long-lead development from these providers, which in turn will be very dependent on funding from Congress.

HEOMD is having much discussion with SMD on what to do with sustained surface activities, and there are different questions being fielded by both HEOMD and SMD. How does the presence of humans affect measurements? The cooling systems used by humans create water (condensate) that could bias data collection. Space suits will need to be modified and modernized, which will also take funding. The 2024 suits will be built in-house, and a Request for Information (RFI) has been released to develop suits for 2024 and beyond.

General Lyles asked: when and how will Gateway be launched? Mr. Bowersox said the first Gateway element is scheduled to launch at the end of 2022. Mr. Mike Gold, Chair of the NAC Regulatory and Policy Committee (RPC), and employed by Maxar Technologies, said Maxar would be responsible for PPE for the first year. PPE will be commercially launched using commercial practices. Mr. Gold praised HEOMD its rapid response in the PPE procurement.

Mr. Bowersox continued that the next part of Gateway is HALO, which will be built by Northrop Grumman, and which will launch roughly six months to a year after PPE. Both the PPE and HALO efforts are well under way. General Lyles said he had been hearing from some contractors that they are having some difficulty reacting so quickly; he was a little concerned about fidelity of proposals that are coming in. Mr. Bowersox said that everyone is leaning forward and working very hard to determine that the proposals are executable. A key part of HLS will be the period after the first awards, which will allow the proposers to re-price based on the final set of requirements. Mr. Gold commented that from the contractor perspective, the proposers have been working on the technology for decades; the quick procurement is what has changed. He noted that the emphasis from NASA has been on safety and getting it right. Mr. Borghese commended the whole team for accelerating procurement. He asked if there were any backup plans to support the 2024 target if NASA remains on a Continuing Resolution (CR), with no plus-up: is safety being slighted with the accelerated schedule? Mr. Bowersox said if NASA remained on a CR, risk will increase without the additional funding, which will likely necessitate a 2025 date. More data is needed from the proposers. He could not say absolutely that NASA would make 2024 on a CR, because there is a point where too much pressure can hurt the effort. He did promise that if he saw a safety issue, he would speak up.

Ms. Krista Paquin commented on the use of nuclear propulsion and asked how technology development was being balanced in Artemis. Mr. Bowersox said that the federated board determines some of the balance. If NASA wants to go to Mars in 15-20 years, SEP will be ready. Nuclear thermal propulsion would be much more expensive to develop. Dr. Alan Epstein suggested that it would be good to have a study on reducing mission risk by using a faster transit time. Mr. Bowersox noted that there have many studies on these trades; it is still a very long mission, regardless of slightly differing transit times, and propulsion must be very reliable to enable a return trip. Dr. Epstein asked if NASA were studying isotopic power on the surface. Mr. Bowersox indicated that STMD developing a nuclear-powered surface

reactor in a project called Kilopower. Rover power is also in need of isotopic systems. There is also some work in the NEXTStep program for developing lunar habitats. The timing for these projects is probably a couple of years; NASA is discussing some smaller RFIs on the subject.

Planetary Protection Independent Review Board

Dr. Alan Stern, the Principal Investigator for the New Horizons mission to Pluto, presented the final report of the Planetary Protection Independent Review Board (PPIRB), a board chartered by SMD to revisit Planetary Protection policy at NASA, given that there have been vast changes in the scientific understanding of places that might support life in the Solar System (SS). It is now known that Earth is not the only planet in the Solar System with an ocean, but that there other bodies that have subsurface oceans. In addition, much has been learned about prebiotic chemistry over the last several. At the beginning of the Space Age, only larger entities had access to space, but now smaller countries and individual corporations can field missions to space. Given these changes, the NAC recommended that NASA take a fresh look at Planetary Protection, a discipline that originated in the 1960s. Following a previous recommendation from the NAC, the SMD Associate Administrator, Dr. Thomas Zurbuchen, chartered the PPIRB to freshly assess how to treat so-called forward and back contamination risks that are inherent to space exploration. The resultant PPIRB report issued 80 findings and recommendations, which are now being reviewed by the National Academies. This was a quick study (90 days) that concluded at the end of September 2019; the report was released on October 18, 2019. The Board was composed of a broad cross-section of expertise: planetary scientists, biologists and representatives from the industry such as SpaceX, Lockheed Martin, Blue Origin and the Commercial Spaceflight Association. The Board heard nearly 100 in-person briefings, and additional briefings were heard by teleconference.

The report's findings and recommendations were aimed at clarifying and streamlining planetary protection processes within NASA, advancing planetary protection protocols with modern technologies, reducing planetary protection burden on missions, and advancing planetary protection policies for private sector missions. All of the findings and recommendations represent a consensus view of the PPIRB. The report is divided into specific topics: Planetary Protection Categorization, Human Spaceflight, Mars Sample Return (MSR), Ocean Worlds, and Private Sector Missions.

Dr. Stern highlighted key findings, beginning with a finding that recognized the evolution of Planetary Protection as a discipline. The PPIRB finds that because things are rapidly changing in terms of both science and access, the discipline should be looked at re-assessed regularly, every five years or so. In addition, the Board recommends that NASA establish a standing forum for the discussion of planetary protection issues, and that the forum have all the necessary players, including internationals, to meet with some frequency. General Lyles asked if the Space Studies Board of the National Academy of Sciences was appropriate to the task. Dr. Stern responded that there were are pros and cons to this approach.

Regarding the Planetary Protection Office (PPO) at NASA, there have many changes in staff, and the new Planetary Protection Officer has taken a much more modern viewpoint. Moving the PPO from SMD to the NASA Office of Safety and Mission Assurance (OSMA) was brilliant and long overdue. The PPO's location in SMD was thought to be a conflict of interest. Accordingly, the PPIRB recommended that NASA adopt an explicit process within the Agency to ensure that planetary protection policies and processes are applied consistently. Regarding NASA control, the Board felt that the Agency can exert a degree of control over the behavior of space actors with respect to behaviors, particularly in regard to sample return. Almost every private sector entity wants to do business with NASA, thus NASA has an opportunity to link good planetary protection to future business. The PPIRB recommended that NASA should do this. Over the longer term, NASA should work to find a suitable home for planetary protection within the Federal Government, as a one-stop regulatory shop. Mr. Borghese suggested that it might be

better to jump straight to the United Nations to establish this framework. Dr. Stern thought it was better to get the U.S. house in order first, because most of these first efforts are domestic in nature. Mr. Gold agreed, adding that Dr. Lennard Fisk, the current American president of the international Committee on Space Research (COSPAR), also provides a natural conduit to the rest of the world. Dr. Stern will brief the PPIRB results to COSPAR in November 2019.

Dr. Stern continued in his presentation, covering the PPIRB recommendations. The Board recommended that NASA revamp its planetary protection methods, noting that the current practice of using spore counts to assess contamination are 1970s-level biology. Specifically the PPIRB recommended that NASA conduct research so as to adopt more modern (molecular) techniques, recognizing that the effort will take some time and money. These techniques should also be reviewed every 3-5 years. The Board also recommended that NASA re-evaluate its planetary protection categorizations for the Moon (from I to II), and Mars (II vs IV), because science has come to understand much more about these worlds. The consensus view on the Moon is that it has no real biological potential, thus its planetary protection category could be relaxed from Category II to Category I. There are places on the Moon, permanently shadowed regions (PSRs), that perhaps could preserve astrobiological materials, such as amino acids from comets and meteorites. PSRs would retain a Category II rating. In the case of Mars, some biologically insensitive areas of the surface and subsurface could be recategorized as II, rather than IV. The PPIRB also put forth a major recommendation to accelerate a plan, in the very near term, to develop a Mars Sample Return Facility (MSRF) without jeopardizing the cost or schedule of Mars Sample Return (MSR). The MSR mission could be delayed or sidetracked if an MSRF plan is not accomplished.

Human missions to Mars would introduce orders-of-magnitude more terrestrial organisms than any robotic mission; this needs to be recognized and accepted. NASA planetary protection planning for human missions to Mars, and the communication of those plans, are at present immature. NASA should quickly begin to prepare to communicate to the public all aspects of planetary protection planning for human missions to Mars, analogous to NASA's proactive treatment of preparing for the launch of nuclear-powered spacecraft. The PPIRB's view is that planetary protection science issues have not been well aired by NASA. Dr. Stern highlighted selected findings on Ocean Worlds, which is currently a priority for SMD, as it is planning missions to the Jovian moon, Europa and the Saturnian moon, Titan. The PPIRB found that current planetary protection categorizations for these worlds are likely too severe, as it is highly unlikely there is any putative indigenous life in these subsurface oceans.

General Lyles stated that an item or two from the briefing could be taken to the National Space Council. Mr. Gold felt that planetary protection modernization was a timely issue, and thanked Dr. Zurbuchen for chartering the PPIRB, as it is particularly important that the request had emanated from SMD. In terms of implementation, he asked Dr. Stern how he saw the effort moving forward. Dr. Stern thought the question would be better directed to NASA, and that the Board feels that the vast majority of the recommendations are relatively easy to implement, and will not require other players. He added, however, that the Board wanted to see these worlds protected at a responsible level, and would like to see NASA leadership in mapping these changes. COSPAR is an excellent forum for this. Dr. Wadhwa commented that it was important to highlight that this effort was driven also by the National Academies, and asked if the Board had considered creating an equivalent of Solar System "national parks." Dr. Stern said the concept has been discussed by others, who had endorsed the idea of having zones of preservation of areas that have high astrobiological interest, such as on Europa or in PSRs on the Moon. It would be effective to have international buy-in on such an idea.

Mr. Morhard thanked Dr. Stern for the overdue effort in planetary protection overhaul, and especially acknowledged the concern about the MSRF, and implementation plans. Mr. Borghese recounted how in the past, three rockets that went to the Moon failed, due in part to planetary protection treatment; he felt that the PPIRB report would help to improve planetary protection technologies. Mr. Miles O'Brien asked

Dr. Stern to offer thoughts on how planetary protection issues could be communicated to the public. Dr. Stern noted that the Board discussion had not been one-dimensional, and that there had been a wide difference of opinion, scientifically, about how to treat sensitive sites. The IRB agreed, by consensus, that the value of sending humans to Mars outweighed the potential for contamination. The IRB believed, however, that the public has not given much thought to the issue, and that public opinion might be dominated by science fiction. The Board's recommendation is to communicate planetary protection concepts carefully, and as soon as possible, to road-test the concepts. Dr. Epstein commented that there are spacecraft from multiple nations now on the Moon and at Mars. In civil aviation, the UN oversees environmental concerns, and perhaps might be appropriate in this case to oversee extraterrestrial environments. Dr. Stern returned to his previous comment about focusing domestically first. Mr. Gold noted that his NAC Regulatory and Policy Committee crafts its recommendations to the U.S. so as to be easily adopted by internationals, and added that it was well worth the wait for Dr. Stern's leadership of the PPIRB. He shared Dr. Stern's view on the value of reporting to COSPAR and to Dr. Fisk, and added that Dr. James Green, NASA Chief Scientist and former Director of the Planetary Science Division in SMD, is also on COSPAR's panel.

Human Exploration and Operations Committee Report

Mr. Wayne Hale, Chair of the Human Exploration and Operations Committee, provided his report. Major activities since May 2019 included an examination of *The Origins of 21st Century Space Travel* (Asner and Garber, eds.), a discussion of how policy was re-shaped around the time of the Columbia Shuttle accident, which was very helpful to the Committee. It received briefings on alternative architectures in private sessions, which was useful to hear and ponder. The Committee took extensive fact-finding tours and meetings at the Michoud Assembly Facility (MAF) and Stennis Space Center (SSC), where members viewed the hardware for SLS, Orion structural developments, and the B-2 test stand used for Green Runs.

The Committee received a status of National Space Council actions from the NASA Chief of Staff, and received briefings from HEOMD, ISS, SLS Green Run Management, Exploration Systems, Advanced Exploration, LEO Commercialization, STEM Engagement and Outreach, as well as from individual program managers from SLS, Orion, the Commercial Crew Program (CCP) and the Launch Services Program (LSP). The Committee also heard from the Marshall Space Flight Center (MSFC) Advanced Analysis Group on why the Artemis architecture is what it is. Mr. Hale, in response to a question, recommended that General Lyles be briefed by the Artemis managers, but cautioned that some information is still embargoed due to procurement proceedings. Hence the NAC may want to wait a bit before arranging detailed briefings. The Committee also represented the NAC at the NASA Aerospace Safety Advisory Panel's (ASAP) quarterly meeting in September 2019.

Mr. Hale highlighted a Committee briefing from the LSP, an organization that has evolved a more commercial approach toward providing service. The Committee believes that LSP is an excellent example of how NASA can move forward efficiently in other areas. LSP tries very hard to be unobtrusive, and has adopted a customer-oriented role model for how the rest of the Agency can work. The LSP serves as an integrative body; its staff is technically astute, and helps to provide certification to many science flights with limited launch windows. LSP also coordinates with a multi-agency federal board, the Current Launch Schedule Review Board (CLSRB), to coordinate launches. LSP is working with the traditional providers as well as the emerging providers.

The Committee received briefing a from Mr. Sam Scimemi on the status of the ISS, the centerpiece of exploration and model for a new future in space. Committee members heard about Increment 61, which is currently comprises two Russians, three Americans, and one ESA astronaut. This Increment began in early October 2019, and will run to early February 2020. The ISS crew is engaged in many activities, including a number of extravehicular activities (EVAs) to upgrade batteries, and is preparing for the

arrival of the Japanese Space Agency's (JAXA) H-II Transfer Vehicle (HTV), as well as a number of commercial cargo resupply vehicles by the end of 2019. Supplies for repairing the Alpha Magnetic Spectrometer (AMS) will also arrive during the last quarter of this year, in addition to technology demonstrations on that are designed to feed forward to Moon and Mars. The Human Research Path (HRP) to risk reduction still has considerable technology gaps to overcome. The top risks remain radiation-related, which cannot be solved on ISS, because it orbits below the Van Allen Belts. Cosmic rays have yet-to-be-determined effects on humans. As an example, Apollo astronauts reported experiencing strobe-like light-flashes as cosmic rays presumably stimulated their retinas. Nutritional and other medical issues, however, can be solved by continuing research on ISS.

Boeing is preparing to stack its Starliner vehicle for a Pad Abort Test, scheduled for early November 2019. A Boeing Crewed Flight Test (CFT) is trending toward early 2020 launch readiness. The SpaceX Crew Dragon Static Fire Anomaly investigation is complete, and SpaceX is preparing to do another hot fire test, after which it will mate the spacecraft on a used Falcon 9 vehicle and do an in-flight abort test. The SpaceX Demo-2 is trending to first quarter 2020 launch readiness. NASA could well have two crew spacecraft ready for flight to ISS by mid-2020.

Mr. Hale reviewed the Moon before Mars rationale, stressing the importance of both economic development effects, and the need to learn as much as possible about operating in deep space while closer to home. General Lyles commented that one thing that seemed to be missing from NASA's Moon to Mars theme is the appeal to the average American citizen. Mr. Hale said that this is why he underscored his discussions about the economic impact of the space program. For example, space exploration technologies enabled the present Global Positioning System (GPS), and accelerated the production and evolution of today's integrated circuits. Quantum computing research at NASA Ames Research Center's supercomputing facilities is addressing computations beyond the limits of Moore's Law. High-tech jobs will eventually replace a considerable sector of the service job sector. Mr. Tony Cole commented that this would be a good time to campaign on what Apollo brought to fruition in the past, and what Artemis could do for the future, in terms of societal and economic dividends. Mr. Morhard commented that a new generational achievement is needed, given the turbulent times. Mr. Hale agreed, commenting that Apollo 8 did much to ameliorate the events of 1968. Mr. Gold said that NASA needs to get out of the "space bubble" and complimented Administrator Bridenstine and Deputy Administrator Morhard on their outreach efforts to the public.

Mr. Hale addressed activities in the Artemis Phase II, wherein NASA continues to build capabilities for Mars missions. The vetting process is going on now to determine what NASA can afford and actually do. During Apollo, there was much internal discussion of orbits and rendezvous approaches. Originally, Apollo was going to land a much larger vehicle configuration on the lunar surface, but physics eventually determined the best approach, as it will do for Artemis. The physics that is driving the current lunar architecture is based partly on what is possible at present. The only rocket viable to get to the Moon is the Falcon Heavy. There are new rockets coming on line, and these new players are being driven by the current competition. Mr. Hale displayed an animation of the NRHO from three perspectives, which illustrated some benefits of the orbit. NRHO allows constant communication with Earth, and access to all parts of the lunar surface. The orbit is more elegant and efficient in terms of propulsion than the brute force approach used for Apollo. The downside is that the orbit necessitates a number of transfers, and it takes the crew 6.5 days to get back to Earth. The schematic is as follows: Orion goes to Gateway, the crew transfers to the HALO habitat, then to the lunar lander, the Moon, back to Gateway, back into the Orion vehicle, and then to Earth. This approach is based on many decades of trade studies with respect to masses, trajectories, etc.

The industry is coming in with proposals on how to improve the lunar architecture in November 2019. Trade studies are comparing storable fuels (hypergolic fuels) and cryogenic stages. NASA is looking to

nimble, creative private companies to come up with new ideas. Dr. Epstein commented that it seems like everything is on the table, and that NASA risks hobbling itself with the current fueling plan. Mr. Hale noted that NASA must still figure out if ISRU is too hard for refueling; Exploration must get to the next step and modify the decision afterward. Mr. Borghese thought the Gateway made the most sense for eventual traverse to Mars. Mr. Hale noted that the HALO habitat presents virtually zero technology risk, while PPE carries a bit of risk, based on the xenon refueling question. Building the lunar lander is the most risky aspect. Additionally, NASA cannot sign the lander contract until Congress appropriates a \$1.6B augmentation. Human Landing Systems proposals are due November 5, 2019, and space suits are also in work. An RFI was issued on October 4, 2019, seeking transition to 2025 and beyond.

NextSTEP habitat prototype testing is now under way as a follow-on to the HALO. Five full-sized ground prototypes have been delivered for testing. In the last year to 18 months, SLS has come together impressively. The Committee believes that the SLS program have most problems behind them; engines are being installed, and the Core Stage is ready to ship very soon for its Green Run test. Planning is under way for a cadence of one SLS flight per year, one of which could carry the Europa Clipper. SLS is using heritage steel cases for solid rocket boosters for the first flight, after which Artemis will switch to carbon fiber cases. There are enough Shuttle main engines for four flights, and planning is on schedule to procure for long-lead items for flights beyond the first four. Payload plans are rising steadily, with an eye to eventually transporting 40MT to the Moon.

The Committee visited the B-2 test stand, where the Saturn V was tested, and where the Core Stage will be tested. The Committee reviewed critical path items for Orion's Artemis I flight, and saw that Artemis II is also progressing. For Orion, the top worry is budget, followed by supply chain.

Mr. Hale presented his Committee findings and recommendations to the Council:

Recommendation – Human Lunar Lander Development for Safety

NASA should review, with an acceptable team, the requirement for in flight testing of the HLS. Serious consideration should be given to demonstrating through flight test the ability to deorbit, land on, and ascend from the lunar surface under the expected physical and environmental conditions.

The Council accepted the recommendation.

Recommendation – Longevity of the International Space System

Perform an analysis of the safe and useful life of the ISS past 2028 with emphasis on the structure and other critical systems that cannot be replaced on orbit.

The Council accepted the recommendation.

Finding – Supporting the \$1.6B proposed budget for 2020

The HEO Committee believes NASA has done a credible job estimating the 2020 funding total for Artemis to meet its goals for 2024. \$1.6B is considered a reasonable estimate of the first-year costs toward the 2024 landing. The HEO Committee acknowledges that even with the full 2020 funding request of \$1.6B, accomplishing planned activities by 2024 will be aggressive, challenging, and difficult. The HEO Committee applauds NASA not raiding other Directorate budgets to fund the Artemis program. An aggressive drive toward the 2024 deadline has prompted a sense of urgency within NASA to meet its goal. Programs, hardware and

deliverables are proceeding at an unprecedented since Apollo, on or ahead of schedule. Related technology advances are proceeding rapidly. We believe proceeding without this funding level in 2020 will result in unacceptable risk to schedule and mission. Additionally, funding should be provided in a timely manner in order to avoid schedule slip and to maintain the current impressive momentum within the program. The committee therefore endorses the 2020 and follow-on budget request and recognizes it to be the top priority and threat to the success of the Artemis program.

After some debate about the magnitude of risk, the Council settled on the words “substantial” or “significant” to describe risk. The Council then accepted the finding.

Finding – NASA Should be Mindful of Competing with Industry in LEO Commercialization

NASA has unparalleled brand value and significant resources with which nascent industry entities in the commercial LEO market are unable to compete for the same potential customers. NASA’s recent initiatives to stimulate demand for a LEO market for which it will be one of many customers are laudable. But care must be taken to prevent unintentional consequences. For example: highly subsidized rates for accommodations aboard the ISS for Private Astronaut Missions may stimulate demand in the short term, but the ability to simply “purchase” these accommodations from NASA will not facilitate acquisition of the knowledge necessary for longer term operation in LEO by non-NASA platform providers. If NASA provides a heavily subsidized fee-for-service option leading up to the transition from a government to commercial platform, the operating entity will not have gained the necessary knowledge and experience to independently keep astronauts safe and well during their stay.

Mr. Gold raised a concern about the finding being misconstrued as a threat to the current LEO procurement, as he had not seen good Congressional support for the recent procurement Appendices. - Mr. Bowersox said he was comfortable with the language of the finding. The Council accepted the finding. Ms. Paquin asked Mr. Bowersox about policy governing the acceptance of proposals. Mr. Bowersox said that the policy is being reviewed, being that it is difficult to walk the line between loss-leaders and realistic pricing. Mr. Gold commented that “LEO commercialization” is not a well-understood phrase and should be replaced by “human space flight commercialization.” Mr. Morhard issued a caveat on NAC independence, cautioning the Council to refrain from asking a NASA Associate Administrator about the acceptability of its findings or recommendations.

Mr. Hale presented two findings directed to the HEOMD Associate Administrator.

Finding – Schedule

The setting of a near term schedule goal (landing on the moon by 2024) has led to a change in the culture and streamlined decision-making, new acquisition methods, etc., and should keep it up even if the schedule slips.

Finding – Launch Services Program (LSP)

The service attitude and culture of the LSP are commendable to build a team that collaborates with multiple parties to achieve a launch goal. We believe that the Artemis Program (all the elements such as SLS, Orion, HLS, Gateway, et al.) should study the way LSP operates and use the applicable processes and attitude and culture as much as is practical.

Mr. Gold applauded the first finding, and suggested changing the wording to be slightly stronger. Ms. Paquin felt that it was an important Pathfinder finding, and suggested it be directed to the Agency. Ms. Paquin undertook to re-write the finding. Dr. Paté-Cornell said that she particularly like the LSP finding, which raised a question of integration of systems. She expressed concern about consistency among the organizations providing subsystems, and suggested the Council hear a briefing on how NASA is doing systems integration, and how the whole program comes together. Mr. Hale completely agreed and recommended that Mr. Wayne Jermstad give a presentation to the Council in the future.

Mr. Hale ended his briefing by noting that the EVA Chief, the ISS Chief Engineer, the head Flight Director, the Public Affairs speaker, the manager of the ISS Vehicle Office, and the Branch Chief of Robotics Operations, are all female. There are increasing numbers of women in high places in NASA because NASA is choosing the best candidate for the job. NASA should get more credit for making great progress in this area, and should also actively take more credit for it. NASA can do better, however, in recruiting more persons of color. Dr. Epstein commented that these facts also have great value as a recruiting tool. Mr. Morhard said that he was not yet satisfied in that there were enough leaders in NASA from diverse groups; NASA has much more work to do. Mr. Gold commented that diversity is key to innovation, which is also key to competing with China. He noted that diversity and the values of a free and open society will always trump a homogeneous, repressive regime.

Regulatory and Policy Committee Report

Mr. Mike Gold, Chair of the Regulatory and Policy Committee, presented his report. The Committee is comprised of some of the best industry representatives, who have been putting in a lot of time on the Committee charter. Mr. Gold expressed great pride in the way the big players in the space industry have been working together collaboratively to improve regulation and policy elements for NASA. The Committee has held two meetings since the last Council meeting, during which it reviewed, revised, and adopted a recommendation entitled: Principles on Space Resources. The major reasons for this one recommendation is that the Committee believes that NASA must be able to use the resources it finds as it explores the Solar System, particularly if the goal of Exploration is to support a sustainable program. The Committee does not want to hinder the extraction and utilization of resources. The Committee believes it is vital for the U.S. to lead this policy discussion. If NASA does not take the action, a lack of clear and consistent global policy could result in confusion and conflict.

Recommendation – Principles on Space Resources

The Committee recommends that NASA, in coordination with the Department of State, the Department of Commerce, and the National Space Council, adopt principles regarding the extraction and utilization of Space Resources as set forth in Annex A.

Annex A

Principles on Space Resources

Principle 1

Abiotic space resources (or simply “space resources”) shall be extracted in a manner that fully complies with the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies. In this context, the term “extraction” includes but is not limited to (i) the extraction of resources from the interior of a celestial body and (ii) the recovery of resources from the surface of a celestial body.

Principle 2

The extraction of space resources should be conducted in a manner that takes into account the United States' commitment to the United Nations Guidelines for the Long-term Sustainability of Outer Space Activities.

Principle 3

The extraction and utilization of space resources does not constitute national appropriation under Article II of the Outer Space Treaty.

Principle 4

Per Article VI of the Outer Space Treaty, States shall authorize and supervise the extraction of space resources from celestial bodies.

Principle 5

States' domestic laws should facilitate government and non-government extraction and utilization of space resources as well as the ownership of those resources.

Principle 6

The principle of due regard, consistent with Article IX of the Outer Space Treaty, should be taken into account by any State authorizing the extraction of space resources. If the State responsible for authorizing the extraction of space resources has reason to believe, based on the information described by Article XI, such activities would result in harmful interference, consistent with Article IX, the State shall engage in consultations with the affected States.

Principle 7

States shall share scientific information with the international community resulting from activities related to space resource extraction and utilization, to the greatest extent feasible and practicable, on a good-faith basis, and in compliance with national laws, including but not limited to export controls as well as protections for intellectual property and national and commercially sensitive data.

Principle 8

States shall inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, in compliance with national laws, including but not limited to export controls as well as protections for intellectual property and national and commercially sensitive data, regarding the nature, conduct, and location(s) of authorized space resource extraction activities. States shall also provide timely notice to the Secretary-General of terminated space resource extraction activities.

Dr. Epstein asked: is there a clear consensus that NASA has the authority to do this? NASA has no authority over the Moon and planets. Is it NASA or the U.S. Government? Mr. Gold noted that because NASA sets its own policy matters, it could set the precedent for the rest of the U.S. government, private sector, and other nations. General Lyles suggested that the recommendation state that NASA should develop the principles, and then present and recommend them to other agencies. Mr. Gold offered to alter the recommendation's language to say that the Committee believes that NASA should adopt the principles first, and then advocate that others do so. Dr. Epstein said he thought that NASA should not formulate the principles, *per se*, but should work with other agencies to formulate them, and then agree to adopt. General Lyles suggested using the first paragraph on Principles on Space Resources as the finding, and then changing the recommendation along the lines of discussion.

Mr. Gold said that the key principles on space resources were derived from the UN Outer Space Treaty of 1967, as it is a treaty of principles that describes goals and objectives, and does not contain proscriptions. Nearly all UN members are signatories to the Treaty. Article II of the Outer Space Treaty prohibits the national appropriation of resources of a body. Dr. Epstein referred to the controversy over the Law of the Sea Treaty, and felt many nations would take exception to the principles outlined under the Committee recommendation. The U.S. has not ratified the Law of the Seas Treaty, nor the Moon Treaty. Mr. Gold said he had written the principles while being very cognizant of these treaties. Germany and Australia support the Moon Treaty, which is why it is important for the U.S. to adopt a stance. Dr. Epstein felt the language seemed to support U.S. legal protections that allow companies to extract resources. Mr. Gold said that the Committee had been focused on Artemis, and was looking to head off conflicts with CLPS, or with having rovers on Mars. Mr. Borghese thought the language could be perceived as a land grab by the U.S. Mr. Gold said the Department of State had briefed the Committee, which had crafted the principles language to be as mild as possible, as they are grounded in the Outer Space Treaty. Dr. Epstein asked if the Committee would want to add “atmosphere” to the subsurface and surface, because on many planets, the atmosphere contains valuable resources as well. Mr. Borghese suggested including some language about excluding military activities. Mr. Gold noted that since the proposed effort would be a NASA effort, the language could be added if the principles flow to other agencies and entities. Mr. Gold emphasized terms such as “due regard” and “harmful interference,” noting that the idea behind the recommendation is to provide clarity and transparency. Asked about the mechanism for the end-product, Mr. Gold envisioned the pathway as the subject of a NASA Policy Directive, followed by the Users’ Advisory Group to the National Space Council, and then to The Hague. Afterward, the Legal Subcommittee of the UN Committee on the Peaceful Uses of Outer Space could be briefed by the Department of State.

Public Input

[Mr. Gold’s presentation was interrupted briefly to meet the previously announced schedule on the NAC agenda for “Public Input.”]

A member of the public asked of Mr. Gold: Is the UN the only authority you are considering going to? Mr. Gold said that he wanted to begin with The Hague, as an example of other non-governmental organizations (NGOs) NASA might approach, and any other international group that is relevant.

Mr. Keith Cowing asked the Council: Are you bothered by the fact that nobody knows what the NAC does, or that NASA does nothing to promote what the NAC does? Mr. Morhard said that he differed with Mr. Cowing’s view, in that the NAC is having serious exchanges. General Lyles said that the NAC is very much concerned about getting public awareness of not just what the NAC is doing, but NASA. He appreciated the comment and took the point. Mr. Gold said he had always noted strong attendance at COMSTAC meetings, but that he had not seen it at the NAC and did not know why. He asked Mr. Cowing what he felt the NAC could do differently. General Lyles asked for a media viewpoint. Mr. Miles O’Brien commented that the NAC is usually focused on communicating to the NASA program managers, which does not make for the most compelling fare for the public. He noted that everyone in the room is very engaged, but was not sure having cameras and music would add value to the proceedings. Mr. Cowing suggested inviting people of the Artemis generation to the NAC meetings, and providing one camera and one microphone. Mr. Morhard observed that cameras change things, and noted that when the Senate became televised, debate evaporated. He felt that the charter of the NAC has a specific purpose, which is being carried out very well.

Dr. John Rummel praised Dr. Stern’s PPIRB presentation as excellent and cogent.

Mr. Al Tabbers said he greatly appreciated the depth of the comments, and did not feel the general public would be interested, because it is hard to keep people engaged. Having attended the recent International Astronautical Congress (IAC), he believed that NASA had been very receptive to public comments during the Congress. General Lyles noted that the larger issue is whether the general public is interested in the workings of the NAC and issues pertinent to space.

Regulatory and Policy Committee Report (continued)

[Mr. Gold's presentation and Council discussion then continued where it had left off.]

Ms. Paquin, referring to the charter of the Committee and its recommendation, thought the principles were appropriate in scope for what Administrator Bridenstine was seeking, and that it would be up to the NASA Administrator to decide how to respond. General Lyles said he would try to capture the Committee recommendation with more concise language, and would rather provide the set of principles as a draft consideration for NASA. Mr. Gold said he had socialized the issues with Administrator Bridenstine and Dr. Scott Pace, Executive Secretary of the National Space Council, and that the important thing at this point was for the NAC to flow the recommendation up to NASA leadership, who can then decide how to deal with it. Dr. Epstein felt that less is more, and that the finding should focus on the importance of principles, and that the recommendation should be that NASA work with the appropriate entities to formulate a set of recommendations consistent with the UN Outer Space Treaty. Mr. Gold agreed to reformulate language and present the results the following day.

Mr. Gold then addressed other issues on his Committee's agenda. Procurement reform is a top concern. Mr. Gold quoted Mr. Doug Loverro as saying the U.S. has to "out-entrepreneur" the Chinese, because it cannot outspend them. The Committee is therefore looking at maximizing and optimizing procurement. The success of the commercial off-the-shelf (COTS) program has resulted in innovative procurement reform, and could be spread to the Department of Defense, for example. The second issue is spectrum management, which is important to preserve for both governmental and commercial activities. The third issue is Planetary Protection reform in COSPAR, and the fourth issue is Intellectual Property reform. Mr. Gold has asked for a briefing on the NASA response to recent Committee recommendations on these issues. Mr. Morhard noted that SMD has already outlined the first steps of an implementation plan for Planetary Protection reform, and that the Planetary Science Division has been tasked to work on the MSRF. Dr. Wadhwa added, with respect to MSRF, that there is a Working Group on returned sample science, headed by Dr. Mike Meyer, that is also working on MSRF.

At the end of the day's session, some general remarks were made. Mr. Hale said he was concerned that the NAC missed a meeting this year, and suggested a catch-up meeting. General Lyles agreed, thinking that a virtual meeting may suffice before the next face-to-face meeting. Mr. Morhard raised the idea of a new subcommittee to help with the intersection of SMD and HEOMD objectives, noting that SMD Associate Administrator Zurbuchen is looking at forming a Lunar Science Committee.

November 1, 2019

Remarks by NAC Chair

General Lyles opened the meeting, and Ms. Rausch made some brief administrative announcements.

STEM Engagement Committee Report

Mr. Daniel Dumbacher, Acting Chair of the Science, Technology, Engineering, Mathematics (STEM) Engagement Committee, presented his report virtually via teleconference. He praised Mr. Mike Kincaid, Associate Administrator, Office of STEM Engagement (OSTEM), and his team, for having done a tremendous job. STEM Engagement is in the midst of a government-wide, five-year Federal Strategic Plan implementation, which encompasses the oversight of two committees. The plan's vision and aspirational goals are far-reaching and challenging, with different Federal agencies are associated with different objectives. NASA's chosen objectives are: foster STEM ecosystems that unite communities; increase work-based learning and training through educator-employer partnerships; and encourage transdisciplinary learning. He presented his Committee recommendations.

Recommendation – STEM Integration Across Agency

The STEM Engagement Committee (Committee) greatly appreciates how the Office of STEM Engagement (OSTEM) is working to increase understanding among Mission Directorates and Centers via the STEM Engagement Council. The Committee also recognizes the challenges of this effort and the additional work necessary to identify potential improvements. The Committee recommends additional efforts at cross fertilization and understanding among the NAC Committees on the STEM activities across the Agency. The Committee clearly sees a need for a more thorough understanding of the current goals, objectives, and status among the Mission Directorates and Centers concerning STEM activities and how these activities support the Agency meeting the goals and objectives of the Federal Five-Year STEM Strategic Plan.

Mr. Dumbacher related that Mr. Kincaid had met with the NAC Human Exploration and Operations Committee earlier in the week, seeking better coordination, as one example of the integration effort. Mr. Hale noted that there are many reasons his Human Exploration and Operation Committee is interested in STEM education, especially since Exploration will require an educated and technically competent workforce. Dr. Paté-Cornell asked how success in STEM engagement goals would be measured. Mr. Kincaid said that evaluation and performance have been key topics of discussion, and that there is a cross-cutting goal on accountability, part of which is to measure inputs and indicators. There is work being done in the Five-Year Plan to apply National Science Foundation best practices to measuring annual STEM performance goals. Other issues for STEM outreach: Is NASA reaching underserved populations? What is the NASA recruitment process and it is reaching the people we want to reach? Ms. Janet Karika, NASA Chief of Staff, commented that many nations at the recent IAC meeting were asking NASA for its STEM engagement metrics, as other countries need these metrics as well.

General Lyles suggested accepting the recommendation as internal to the NAC, rather than a formal recommendation to NASA, which in turn would ensure that its committees are addressing STEM engagement. He requested a briefing to the full NAC to enable it to understand better where the NAC and STEM efforts intersect. Mr. Kincaid suggested a joint meeting between the NAC Human Exploration and Operations Committee and STEM Engagement Committee. General Lyles agreed, adding that there should be similar STEM engagement with the Science Committee and Aeronautics Committee. Dr. Wadhwa noted that the Science Committee will hear a briefing on the Science Activation Plan for SMD, at which time it would be good to have a STEM representative present to start the interface. Mr.

Borghese also welcomed Mr. Kincaid to attend his next Aeronautics Committee meeting, to learn more about what both aerospace companies and NASA are doing in STEM in the Aeronautics area. Mr. Kincaid said that as the NAC is not the primary audience, he would be happy to brief the individual committees on what it is doing with SMD. Ms. Paquin said that NASA has been seeking approval for HR “excepted service” status, and did get approval for direct hire authority to onboard 3500 employees in STEM areas over the next five years. Ms. Karika said that a key meeting is coming up on the subject of modernizing the workforce. Mr. Cole noted that it was important to modernize the tool sets for these young hires, because they communicate differently than the generation that is retiring. Mr. Kincaid stated that NASA target students younger than undergraduates, and that there are related but different aspects of reaching the younger generation. Mr. Borghese said he had been working with two organizations relative to STEM, which had seen successes with females, but was lagging very behind in black and Hispanic communities.

The Council accepted the recommendation.

Finding – Study on Sparking Interest in STEM

The STEM Engagement Committee (Committee) appreciates the work done to understand the generation and sustainment of “sparking” interest in STEM areas. The expert panel review and literature search provided valuable input to STEM Engagement Strategies. The “Spark” study conducted by Office of STEM Engagement (OSTEM) provides important knowledge and information for future STEM activities planning. The Committee looks forward to seeing the results of the action requesting OSTEM to develop a prioritization strategy for addressing the findings from the Spark study, at a future Committee meeting.

Finding – STEM Alignment and Diversity

The STEM Engagement Committee (Committee) applauds the effort to develop the direct correlation of the Office of STEM Engagement (OSTEM) objectives to the Federal Five-Year STEM Strategic Plan. This effort leads to an architecture enabling student opportunities in STEM activities based on results from the Spark study. As OSTEM proceeds with the on-going planning effort the Committee would like the opportunity to review the resulting relationship of OSTEM activities to the overall Federal plan, and asks that OSTEM provide direct evidence demonstrating the direct support of the Federal Five-Year STEM Strategic Plan. The Committee supports OSTEM’s plan to provide evidence of utilizing intentional activities and methods for assuring STEM activities reach the diverse, under served and underrepresented communities. The Committee also feels that metrics would be valuable to measure the results for reaching out to new communities.

Mr. Dumbacher reviewed NASA’s architecture for enabling student opportunities and contributions, which maps STEM engagement focus areas to eight objectives, and then uses results to feed back into the STEM engagement goals and requirements to improve the system. Currently, Mr. Kincaid and his team are focused on Sphere 1 STEM challenges in the Artemis program, Earth Day activities, and the Mars 2020 rover mission. All of these challenges have success criteria and impacts that can be translated into metrics.

Mr. Gold commented that rural America and the Native American population should not be omitted when thinking about STEM engagement; it makes a huge difference when students can touch actual NASA hardware. Ms. Karika noted that Administrator Bridenstine has been actively working with the First Nations Launch project, a student rocketry program. Mr. Kincaid said the five-year plan notably includes a rural population focus. General Lyles commented that Dr. Aimee Kennedy, Chair of the NAC STEM

Engagement Committee, also leads the Ohio STEM network, which touches rural communities. Her network uses established best practices that can be adopted elsewhere. Mr. Kincaid commented that individual states are often best positioned to show NASA the way. He added that OSTEM is looking at what the research and experts are saying and trying to figure out how to best use its time, and has been asking for feedback on these ideas from the NAC STEM Engagement Committee. General Lyles related that Virginia's Wolf Trap Performing Arts Center have a STEM arts education program that starts at the pre-school level, which has been adopted by the Department of Education, and recommended that OSTEM should consult them. There is also a STEM Committee of the National Space Council's User Advisory Group (UAG), which has recommended that a Space Policy Directive should be written specifically on the subject of STEM. General Lyles requested that the "Spark" study be distributed to NAC members, and hoped to winnow down a "thousand points of light."

Technology, Innovation and Engineering Committee

Mr. Michael Johns, Acting Chair of the Technology, Innovation and Engineering Committee (TI&E), presented his report virtually via teleconference. The scope of the Committee is focused on technology innovation across NASA, and last met on October 29, 2019. The meeting agenda included tours at KSC, updates from Chief Technologist on the current activities at STMD, and briefings describing the Moon as a proving ground for technologies, as well as Mars-unique technologies. The Committee was impressed with how much progress has been made: the ISRU instrument for Mars 2020, the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), has been delivered, as well as the AstroBee robotic system on ISS. Other activities, both planned and active, include the development of a space atomic clock, solar-electric propulsion (SEP), a green propellant initiative, and Mars-unique Entry, Descent and Landing (EDL) technologies.

The Committee provided some observations, the first commending the decision to keep STMD a stand-alone organization, and cited some recent STMD successes. There has been an increased demand to support CLPS and potentially, HLS providers. Cryofluid management at STMD has been particularly well-done. Mr. Borghese asked: Is there a process to transfer these technologies to commercial space activities? Mr. Jim Reuter noted that this process is one of the focuses of the Tipping Point program; the 33 awards made, and there have been some agreements made that will help commercialize these technologies, after which NASA can serve as its customer. STMD is still looking for ways to improve the process. Mr. Gold stated that the Tipping Program has been very effective. General Lyles felt this first observation could be a finding for the NASA Administrator.

The Committee presented an observation on STMD having successfully aligned Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) investments with Agency priorities. Mr. Reuter commented that STMD is trying to maintain its program, but will try to expand efforts if the budget increases. He noted that the Office of Management and Budget (OMB) has shown support for legislative proposals on expanding the program.

The Committee heard a briefing from the Lunar Surface Innovation Initiative, which is focused on ISRU, extreme access and other lunar-focused tasks. The results of an Applied Physics Laboratory (APL) study may lead to a consortium of universities to participate in the initiative. The Committee also heard from Mr. John Hogan on advances in synthetic biology. Future space missions will need a different approach to sustain humans far from Earth, necessitating innovations in food production, vitamins, space medicine, and polymers, much of which may be facilitated by bioengineering practices. The Center for the Utilization of Biological Engineering in Space (CUBES), led by the University of California/Berkeley, is focused on biomanufacturing systems such as optimized plant production, plant-based production of biopharmaceuticals, and pharmaceutical production in cyanobacteria (acetaminophen).

The Committee provided an observation on the great progress being made in the use of the Space Technology Research Institutes (STRIs) and noted that Karen McDonald of University of California/Davis had been recently selected for a Translational Research Institute for Space Health (TRISH) award for a plant-based platform for "just-in-time" medications.

The Committee received a briefing from the Nuclear Thermal Propulsion (NTP) project, which is partnered with the National Laboratories and the Department of Defense in developing flight demonstration studies. The project has been developing fuel elements, and experienced a recent test failure. After receiving recommendations from an independent review team, the NTP is focusing now on spark plasma sintering, and is pursuing multiple paths in manufacturing. Of the two Flight Demo (FD) options NTP had considered, (FD-1: nearest term, traceable, target soonest flight hardware delivery) and FD 2 (near term, enabling capability, emphasis on extensible performance over schedule), Mr. Reuter said NTP did not find FD 1 very promising, thus FD-2 has been the subject of internal and external studies with 10-12 industry partners. The study reports are expected in March/April 2020. The Committee extended a finding on FTP from an initial finding in April 2019. Mr. Hale noted that there is a new Joint Army/Navy/Air Force Propulsion interagency committee studying nuclear propulsion, that will be meeting in Washington, DC, in November 2019.

The Committee presented an observation commending the Early Career Initiative (ECI), that has \$13M committed to the program in Fiscal Year 2020. Two ECI grantees presented their work. Dr. Amy Meier described a project she led with early career scientists and engineers, working on converting trash into useful fuels. The project began in 2018. Most of the team had not done formal rigorous engineering work and used this opportunity to take a concept from white board to hardware. The team designed a rig and used drop towers to test its designs. The finished product is being prepared for a suborbital flight with Blue Origin, which is designing the enclosure, while the team designs the interior. The experience centered on developing early career scientists for infusion into the Agency, and goes far beyond experimental work. It includes pushing back at management, agile management approaches, and learning quickly vs. sloppily. The project had many stakeholder reviews, which greatly helped the effort, and also interacted with different NASA Centers, NASA Headquarters, and commercial partners. There was a lot of human element interaction, team-building, and outreach in the community. Dr. Meier said she had heard from the commercial sector that they expect NASA to develop the trash mitigation effort, and she also felt the experience helped employee retention. The two-year funding for her project was \$2.5M all-inclusive, although she reported a little extra funding toward the end. Dr. Meier said she had obtained funding to proceed with some of the team to work on a Gateway project, starting in January 2020.

Dr. Kevin Grossman described his lunar ISRU project on Molten Regolith Electrolysis, described as being similar to an aluminum oxide refinement method. The Moon is about 45% oxygen by weight, and to get to it, it is necessary to melt regolith at 1600°C. The project is localizing melting of regolith in the operating space to avoid corrosion; the second year will be concentrated on an end-to-end demonstration. The project is partnering with Honeybee Robotics, and is providing an excellent opportunity to learn how research is done at NASA. Dr. Grossman reported having the same funding profile as Dr. Meier. Dr. Epstein asked how much energy is needed to make oxygen in this scenario. Dr. Grossman said about half an ampere per square cm per electrode, with 2 volts across the electrodes. The experiment is limited to 10kW to go into the regolith to melt it. The project is doing a literature review right now, and hopes to have four of five different techniques to test by the end of the first year. Everyone in the core team is an early career scientist. Ms. Paquin asked if the FY 2020 funding level would be maintained? Mr. Reuter said the goal has been to award five grants per year, and to have, on average, one grant per NASA Center. The intent is to maintain this at the five per year level. Mr. Borghese asked Dr. Grossman if he was looking to make the electrolysis a continuous flow process. Dr. Grossman said the method is currently a batch process, because he wanted to be able to siphon out the molten product from the bottom. Eventually, his hope was to develop a continuous process.

Science Committee

Dr. Meenakshi Wadhwa, Chair of the Science Committee, provided her report. The Committee's 10 members have not had a chance to meet since the last NAC meeting, and will hold its next meeting in November 2019. In the interim, Dr. Wadhwa reported having given a presentation to the Space Studies Board (SSB), National Academy of Sciences, on the subject of the SMD Science Plan. The SSB issued findings in line with those from the Committee, and is looking forward to a response from NASA. The Committee also held a brief teleconference on the SMD programmatic status.

Dr. Wadhwa presented a number of science highlights, beginning with ICON, which is looking at space weather in the ionosphere, and studying events that can prematurely decay orbits and present health risks to astronauts. Solar Orbiter (SO), a NASA/ESA collaboration, will be launched on an Atlas V rocket at KSC in the February 2020 timeframe. NASA has contributed to four instruments on SO, which will also collaborate with the Parker Solar Probe (PSP). There is some risk that a Commercial Crew flight will create a conflict in February 2020. As scheduled, SO will arrive during the fifth orbit of PSP, where the two spacecraft will be able to obtain complementary data sets. There will be a special issue of *Nature* on this mission, which seeks to explain how the sun creates the heliosphere.

The NASA Earth Science Division's Temporal Experiment for Storms and Tropical Systems Demonstrator (TEMPEST-D) cubesat, about the size of a cereal box, is a radiowave instrument that measures levels of moisture and precipitation in clouds at different depths, essentially drilling down into the moisture distribution of the atmosphere. TEMPEST-D was able to look down through the cloud layers of Hurricane Dorian and provide useful data on rainfall associated with the storm. The Cyclone Global Navigation Satellite System (CYGNSS), a constellation of eight cubesats, provides important wind velocity information between the 38N and 38S latitudes, with a revisit time of 7 hours. CYGNSS data was provided to forecasters during Hurricane Dorian. The Advanced Land Observing Satellite 2 (ALOS-2, or Daichi 2) satellite, a JAXA instrument, provided synthetic aperture radar (SAR) data showing terrestrial deformation and rupture during the July earthquakes in California, helping disaster agencies to assess impacts.

The Hubble Space Telescope (HST) continues to enable discoveries, and most recently detected water vapor on exoplanet K2-18b, a planet orbiting a red dwarf in the habitable zone. Researchers are getting more information on distant worlds that might harbor life. Combined results from the X-ray Multi-Mirror Mission (XMM) and the Chandra spacecraft have detected a supermassive black hole that blasts out x-rays every 9 hours, a discovery that could lead to novel insights in physics.

The Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-Rex), continues to orbit the asteroid Bennu. Water vapor has been detected on Bennu's surface, and the asteroid is actually spewing volatiles. Currently four potential sites are being considered for a touch-and-go sample collection maneuver. Boulder-strewn fields on the asteroid are proving to be a challenge for the sample collection device. The Mars seismic robot Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSIGHT) has detected numerous seismic events, as of July 30, 2019. The mole, meant to probe beneath the surface, is still unable to make much headway, but the problem is being actively worked. During a discussion on the Mars program status, SMD Associate Administrator Zurbuchen briefed the Committee on Mars 2020, which is making great progress in all areas except cost. The rover is similar in size to the Mars Science Laboratory (MSL, known as Curiosity), and will also carry a helicopter. Mars 2020 is expected to launch on schedule.

The Europa Clipper mission has been confirmed, and will be carrying nine instruments, orbiting Jupiter and doing 45 fly-bys of the Jovian moon. It is believed that Europa has an ice shell encasing an interior ocean. The Clipper mission will be looking for potentially inhabitable areas on Europa, and may launch

as early as 2023. The Dragonfly “octocopter” drone mission to Titan has recently been approved. Dragonfly will investigate Titan’s methane atmosphere, and hydrocarbon ponds and lakes on the surface. It is an exciting mission which may launch in 2026, and arrive at Saturn and Titan in 2034. The mission will have an isotopic power source. The James Webb Space Telescope (JWST), which has had well-known challenges in schedule and cost, is now making its milestones, with a launch date still holding at 2021. JWST will be NASA’s most powerful and complex infrared space telescope, and will be able to look back in time at an ancient universe.

The Committee also heard about aspects of Artemis Phase I, wherein a number of science elements will be developed for a lunar cargo lander project through CLPS. Mr. Steve Clarke of NASA noted that the work is going well, and that NASA is about to conclude its first on-ramp for CLPS. NASA’s VIPER mission is under the same program, and is expected to launch in 2022. The Committee also heard details about a new review of ISS, initiated by Dr. Zurbuchen, and NASA’s cooperative agreement with Center for the Advancement of Science in Space (CASIS). The review Chair is Dr. Betsy Cantwell, and the Executive Officer will be Ms. Ellen Gertsen of SMD. A report is expected in early 2020.

Dr. Wadhwa detailed an SMD response to advice from a May 2019 meeting of the Committee, specifically to a recommendation to SMD to develop a multi-tiered strategy to facilitate diverse teams and safe environments. The SMD response to the recommendation included implementing new grant terms and conditions, adding language to the Discovery and New Frontiers programs on succession planning and developing the next generation of mission PIs, including the establishment of semi-annual PI workshops; undertaking pilot activities that will seek to reduce bias in proposals, based on successful work that has been proven out in HST’s Guest Observer program; and making team operational changes to create more inclusive environments. The Committee is very satisfied with the response, and plans to periodically check in on the effort. General Lyles noted that the response has implications beyond SMD.

Looking ahead, the next Committee meeting will include a Moon to Mars update, a briefing on the PPIRB report, a discussion on Research and Analysis (R&A) innovations at SMD, and a National Academies assessment of SMD Science Activation Program. There are no Committee recommendations or findings to the Council at this time.

Aeronautics Committee Report

Mr. John Borghese, Chair of the Aeronautics Committee, gave his report. He reported on its July 2019 meeting, the last one for Dr. Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate (ARMD), who has since retired from NASA. Topics included the ARMD Strategy Overview and a briefing on Propulsion. The Committee has added a number of industry representative members, bringing much wealth of experience.

Mr. Borghese provided a snapshot of what is happening in Aeronautics. Great changes are coming with the expected integration of un-crewed air vehicles (UAVs) into air traffic systems, advances in urban air mobility (UAM), increases in regional short-haul excursions, and large opportunities for supersonic transport. Studies anticipate a two-order-of-magnitude increase in air traffic over the next 20 years. The benefits of electrified aircraft propulsion (EAP) can provide improvements to current aviation technologies. At present, ARMD is focusing on EAP in small single-aisle aircraft and Regional Jets, and is looking at both fully electric and hybrid electric engines. NASA’s Electrified Aviation Propulsion strategy is focused on needs where NASA feels it can add value: developing certification standards, and demonstrating electrical propulsion architectures and evaluations. One-megawatt electric motors are considered an important part of this focus. NASA recently tested a one-megawatt motor, at altitude, at its Plum Brook Station facility in Ohio. Mr. O’Brien said that he had heard that hybrid systems are too complex and not worth the trouble. Mr. Borghese noted that, nonetheless, some companies are making

major investments in hybrid technologies. Dr. Epstein said that a one-megawatt motor is not terribly powerful, and can be thought of as “mildly hybrid.” A traditional 787 jet has a megawatt of power. He added that as NASA has refined its calculations on EAP, the benefits to single aisle aircraft have dropped to 1-3%; thus fully electric engines may not make much sense unless something else is being done with the electric power. Even an all-electric aircraft does not contribute to carbon dioxide reduction; current aircraft engines are more effective than the terrestrial electric grid by a factor of two. Dr. Epstein felt that a megawatt of EAP might benefit very small vehicles, however, and that a 3-5% improvement could be important.

Mr. Borghese presented a recommendation and a finding:

Recommendation for ARMD Associate Administrator – Propulsion Transformation – Electric Propulsion

The Committee applauds NASA’s research in Electrified Aviation Propulsion. Research is being performed in many relevant areas: aero efficiencies, compliance and certification, tools for better design trades and new materials such as insulators. The Committee recommends that NASA consider developing and maintaining a database of battery and cell test results to share with industry. The idea is to have an energy power storage (e.g., cells, batteries, etc.) laboratory within the current NASA infrastructure dedicated to testing specific electric aircraft propulsion. This lab would test against standardized protocols and make the results available to industry to accelerate the adoption of electrified powertrains. This approach could be expanded to other system components, such as power electronics in the future. The Committee further recommends that NASA explore other promising aircraft electric propulsion technology alternatives, such as fuel cell variants currently in use in automobile and bus transport vehicles. There are potential applications to the Mars mission so it will benefit not only ARMD but also NASA as a whole.

Mr. Borghese felt that a NASA database of battery and cell tests could benefit the nearly 200 US companies that are developing UAVs and UAM. NASA should have an energy power storage lab dedicated to testing specific electric aircraft. General Lyles asked Mr. Borghese to make some clarifications in the recommendation language. Dr. Epstein commented that research on carrying higher voltages at higher altitudes is a core NASA mission that makes sense, but that testing commercial batteries is not the role of the U.S. Government. Battery suppliers supply data sheets. The U.S. Government has already made great investments in battery technology. Mr. Borghese noted that this information tends not to be available to small start-up companies. Dr. Epstein felt that the recommendation could interfere with commerce, and was not sure what role NASA had in getting between battery cell suppliers and purchasers. Mr. Borghese said that he was referring to X57-level battery testing. Dr. Epstein suggested that the Committee make a finding that says there is a lack of widely available information on commercial batteries, and that much more investment and research is needed in high-altitude power transmission technology. Mr. Borghese agreed to make changes resulting in a finding for batteries, and a recommendation for power transmission research.

Finding for ARMD Associate Administrator – Autonomy Strategy

The Committee finds that NASA has developed a reasonable strategy for advancing this important area of contemporary aeronautics research and development. The strategic focus on national level, large scale applications such as future air traffic management, unmanned air systems, and emerging urban air mobility provides both motivation for NASA involvement and rationale for specific targeted programs. In addition, the plan to develop assurance methods for complex, machine learning-based systems recognizes the need to address future aviation autonomy capabilities beyond the reach of industry investment timelines. The importance of the

human operator-intelligent machine relationship is also recognized as a major challenge relevant to the broadest class of aviation systems. Additional areas that require long term NASA attention include cyber-security and -resiliency, especially in the case of networked multi-platform systems-of-systems. A companion NASA technology roadmap focused on stimulating fundamental advances would also be helpful. To facilitate those advances most germane to the aviation enterprise, NASA should continue its collaboration with the universities to increase interest and motivation in autonomous systems, while involving the students since they are the next generation of NASA engineers.

The finding included a lengthy list of suggestions. Mr. Borghese emphasized the inherent difficulty in certifying learning-based systems, and said he had not heard anything from the other NASA Mission Directorates on the subject of cyber-resiliency either. General Lyles suggested adding a briefing on cybersecurity to the next NAC meeting.

Mr. Borghese added that the Committee felt it important that NASA continue to collaborate with universities in the area of autonomy. Dr. Epstein noted that NASA has no role in certification of aircraft; rather, NASA develops technologies, but does not implement or certify them; this is the role of the Federal Aviation Administration (FAA). General Lyles suggested having a finding that describes gaps in the NASA autonomy strategy, and a recommendation to expand NASA research in several areas, such as how to certify non-deterministic systems. General Lyles and Mr. Borghese agreed to work together on a revision.

Council Discussion and Final Wrap-up

The Council finalized and approved the Regulatory and Policy Committee recommendation and one Human Exploration and Operations Committee recommendation. General Lyles commented that in future, the Council would seek to strike a better balance between time for facility tours and time for discussion. Mr. Morhard invited the Council to consult with him freely and provide feedback.

General Lyles, invited the Council members to share any final comments. Mr. Borghese thought the full-day KSC tour had been very valuable and that the presentations were excellent. He felt it was valuable to have tours before the presentations, and that having copies of NAC presentations at least a day in advance would allow better preparation for discussion. Dr. Wadhwa said she agreed with the idea of pre-work, and also supported scheduling NAC meetings a year or two in advance. Mr. Gold thanked the NASA support teams and the NAC, and said he appreciated having Mr. Morhard and Ms. Karika in attendance. Ms. Karika said that she appreciated the important work done by the NAC, and wanted to hear what NASA is doing well, and not so well. Mr. Hale commented that Human Exploration is not the only thing that NASA does, and commended the other NAC members for their excellent work. Mr. O'Brien supported more livestreaming, televising, and YouTube coverage of NAC proceedings. Ms. Paquin extended an invitation to the NAC to consider her as a conduit to mission support, procurement, and issues workforce, promising to help streamline the process. Dr. Paté-Cornell commented on the great KSC tour and presentations, and added that in the future, the NAC may want to address systems integration and consistency of standards, NASA's scheduling problems, and the evaluation of NASA's STEM efforts. General Lyles said he would arrange a briefing on systems integration, and that it would be prudent to wait until the incoming HEOMD Associate Administrator was settled in, before arranging a briefing on lessons learned in scheduling. Dr. Epstein thanked Mr. Gold for his presentation.

General Lyles adjourned the meeting at 11:49 am.

Appendix A Agenda



NASA ADVISORY COUNCIL

NASA Kennedy Space Center, FL
New Headquarters Building
Director's Conference Room, Room 7212

October 31 – November 1, 2019

Thursday, October 31, 2019

10:30 am	<u>Council Public Meeting</u>	
10:30 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
10:33 am	Welcome and Introductions by NAC Chair	Gen. Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council
10:45 am	Welcome to NASA Kennedy Space Center	Mr. Robert Cabana, Director NASA Kennedy Space Center
11:15 am	Remarks by NASA Deputy Administrator	Mr. James Morhard NASA Deputy Administrator
11:45 am	NASA Human Exploration Program Update	Mr. Kenneth Bowersox Acting Associate Administrator Human Exploration and Operations Mission Directorate
12:30 pm	<u>Council Lunch</u>	
1:30 pm	<u>Council Public Meeting</u>	
1:30 pm	Planetary Protection Independent Review Board Final Report	Dr. Alan Stern, Chair
2:30 pm	Human Exploration and Operations Committee Report	Mr. Wayne Hale, Chair
3:30 am	Regulatory and Policy Committee Report	Mr. Michael Gold, Chair
4:50 pm	Public Input	
5:00 pm	Adjourn	

Friday, November 1, 2019

8:30 am	<u>Council Public Meeting</u>	
8:30 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
8:32 am	Remarks by NAC Chair	Gen. Lester Lyles (USAF, Ret.) Chair, NASA Advisory Council
8:35 am	STEM Engagement Committee Report	Mr. Daniel Dumbacher (<i>virtual, for Dr. Aimee Kennedy, Chair</i>)
9:00 am	Technology, Innovation and Engineering Committee Report	Mr. Michael Johns (<i>virtual, for Mr. James Free, Chair</i>)
9:45 am	Science Committee Report	Dr. Meenakshi Wadhwa, Chair
10:15 am	Aeronautics Committee Report	Dr. John Borghese, Chair
11:00 am	Council Discussion and Final Wrap-Up	All
12:00 noon	Adjourn	

Appendix B Council Membership

NASA Advisory Council Members:

General Lester L. Lyles, *Chair*

Dr. Penina Axelrad

Mr. John Borghese

Mr. Tony Cole

Dr. Alan H. Epstein, *Ex Officio*

Mr. James Free

Mr. Michael Gold

Mr. N. Wayne Hale

Dr. Aimee Kennedy

Dr. Margaret G. Kivelson, *Ex Officio*

Lt. General Lee K. Levy II

Hon. Bill Nelson

Mr. Miles O'Brien

Ms. Krista Paquin

Dr. Elisabeth Paté-Cornell

Dr. Meenakshi Wadhwa

Ms. P. Diane Rausch, *Executive Director*

U.S. Air Force (Ret.)

University of Colorado/Boulder

Rockwell Collins ATC

FireEye

Chair, Aeronautics and Space Engineering Board

Peerless Technologies

Maxar Technologies

Special Aerospace Services

Battelle

Chair, Space Studies Board

U.S. Air Force (Ret.)

Former Senator, State of Florida

Independent Journalist

Former Deputy Associate Administrator, NASA

Stanford University

Arizona State University

NASA Headquarters

Appendix C Attendees

NASA Advisory Council Members:

General Lester L. Lyles, <i>Chair</i>	U.S. Air Force (Ret.)
Mr. John Borghese	Rockwell-Collins ATC
Mr. Tony Cole	FireEye
Dr. Alan H. Epstein, <i>Ex Officio</i>	Chair, Aeronautics and Space Engineering Board, NAE
Mr. Michael Gold	Maxar Technologies
Mr. N. Wayne Hale	Special Aerospace Services
Hon. Bill Nelson	Former Senator, State of Florida
Mr. Miles O'Brien	Independent Journalist
Dr. Elisabeth Paté-Cornell	Stanford University
Ms. Krista Paquin	Former Deputy Associate Administrator, NASA
Dr. Meenakshi Wadhwa	Arizona State University
Dr. Patricia Sanders	Chair, NASA Aerospace Safety Advisory Panel
Ms. P. Diane Rausch, <i>Executive Director</i>	NASA Headquarters

NASA Attendees

Robert Cabana, NASA Kennedy Space Center Director
Mike Green, NASA Headquarters
Tim Griffin, NASA Headquarters
Kevin Grossman, NASA Headquarters
Janet Karika, NASA Chief of Staff
Mike Kincaid, NASA Associate Administrator, Office of STEM Engagement
Anne Meier, NASA Headquarters
James Morhard, NASA Deputy Administrator
Wendy Neuerberg, NASA Headquarters
Ashley Nelsen, NASA Headquarters
Sam Scimemi, NASA Headquarters
Heather Scott, NASA Headquarters
Bette Siegel, NASA Headquarters

Non-NASA Attendees

Mary Floyd, Electrosoft, Inc.
Joan Zimmermann, Zantech, Inc.

Webex and Teleconference Attendees

Andrew Abercrombie
Kase Abt
Christopher Aguilar
Deji Akanbi
Asha Balakrishnan
Arthur Beckman
Bill Beckman
Tim Belk
Damara Belson
James Beltz
John Bergstresser

Don Burch
John Burgstrom
Stephen Clark
Victoria Carter-Cortez
Cara Cavanaugh
Angela Clark-Williams
Al Condes
Keith Cowing
Elaine Denning
Miles Doran
Daniel Dumbacher
T. Jens Feeley
Karen Feldstein
Martin Frederick
Jeff Foust
Gene Fujikawa
Chris Gilbert
Robyn Gatens
Beverly Girten
Lori Glaze
James Green
Belinda Hale
Kathryn Hambleton
Brian Harvey
Jiří Hošek
Richard Howard
John Iannuzzi
Michael Johns
Jennifer Kearns
Sagi Kfir
Gilbert Kirkham
Margaret Kivelson
Irene Klotz
Theodore Kronmiller
Julie Lang
Justin Lazier
Frank Ledbetter
James Lochner
David Long
Richard McKinney
Laura Means
Michael Meyer
Gene Mikulka
Michael Nealing
Michael New
Kelly O'Rourke
Bill Peterson
Eric Poole
C Quinn
Jim Reuter
John Rummel

Elaine Seasly
Marc A. Seibert
Robert Singer
Clare Skelly
Philip Sloss
Virginia Smallwood
Marcia Smith
Micheline Tabache
Al Tadros
Julie Wang
Mark Seaburg
James Zimmerman

Appendix D

List of Presentation Material

- Kennedy Space Center Welcome: *Mr. Robert Cabana*
- Human Exploration Update: *Mr. Kenneth Bowersox*
- Planetary Protection Independent Review Board: *Dr. Alan Stern*
- Human Exploration and Operations Committee Report: *Mr. Wayne Hale*
- Regulation and Policy Committee Report: *Mr. Michael Gold*
- STEM Engagement Committee Report: *Mr. Daniel Dumbacher*
- Technology, Innovation and Engineering Committee Report: *Mr. Michael Johns*
- Science Committee Report: *Dr. Meenakshi Wadhwa*
- Aeronautics Committee Report: *Mr. John Borghese*