

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

**NASA ADVISORY COUNCIL**

**Human Exploration and Operations Committee**

**March 26-27, 2018**

**NASA Headquarters  
Washington, DC**

**MEETING MINUTES**

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**Kenneth Bowersox, Chair**

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**Bette Siegel, Executive Secretary**

**Human Exploration and Operations Committee Meeting  
NASA Headquarters  
Glennan Conference Center  
Washington, DC  
March 26-27, 2018**

**MEETING MINUTES  
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**NASA ADVISORY COUNCIL  
Human Exploration and Operations Committee Meeting  
NASA Headquarters  
Glennan Conference Center, Room 1Q39  
Washington, DC 20546**

***Monday, March 26, 2018***

Call to Order, Welcome, & Opening Remarks

Dr. Bette Siegel, Executive Secretary for the NASA Advisory Council (NAC or Council) Human Exploration and Operations (HEO) Committee, called the session of the HEO Committee to order at 11:00 a.m. She announced that the meeting was a Federal Advisory Committee Act (FACA) meeting and, therefore, would be open to the public. Minutes would be taken and posted online, along with the presentations. Dr. Siegel explained that there would be an opportunity for the public to make comments towards the end of the meeting, and she requested that all questions and comments be held until that time.

Dr. Siegel introduced the Committee chair, Mr. Kenneth Bowersox. Mr. Bowersox welcomed everyone to the meeting.

Human Exploration and Operations Overview

Mr. Bowersox introduced Mr. William Gerstenmaier, HEO Mission Directorate (HEOMD) Associate Administrator (AA).

Mr. Gerstenmaier discussed the Administration's Space Policy Directive-1. It states:

*"Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low Earth orbit (LEO), the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."*

Mr. Gerstenmaier explained that the directive is exactly what NASA has been doing and fits well with NASA's plans for the Commercial Crew Program (CCP) and the International Space Station (ISS).

Mr. Gerstenmaier described the Exploration Campaign and the materials presented to Congress for NASA's proposed Fiscal Year (FY) 2019 Budget. The Exploration Campaign calls for commercial and international partnerships in LEO, a return to the Moon for long-term exploration in cislunar space, and research on Mars to inform future crewed missions. The proposed budget will prioritize human exploration and related activities. It provides funding to start transition of LEO human space flight operations to commercial partners and to pursue a cislunar strategy that establishes U.S. preeminence to, around, and on the Moon. At the end of the five years shown in the proposed budget, NASA expects to have:

- achieved uncrewed and crewed test launch of the Space Launch System (SLS) and Orion,
- launched two initial elements for the Lunar Orbital Platform-Gateway (Gateway),
- supported numerous commercial lunar robotic landings and developed commercial lunar landing capabilities to support future NASA mission needs,
- developed key technologies needed to make Exploration more capable and cost-effective, and
- established a pathway to enable a seamless transition from direct NASA financial support to the ISS in 2025.

Mr. Gerstenmaier noted that NASA proposes to restructure and align HEOMD and the Space Technology Mission Directorate (STMD) to enhance NASA's ability to accelerate human exploration beyond LEO. He reviewed the reorganization options currently under review and explained that NASA would assess the options and prepare for implementation by the start of the FY 2019 budget year. The amount requested for the Exploration Campaign in the proposed FY 2019 budget is \$10.4989 Billion (B). Mr. Gerstenmaier noted that the amount is less than the unexpected larger amount Congress recently approved for NASA's FY 2018 budget.

Mr. Gerstenmaier presented a chart showing eight strategic principles for sustainable exploration:

- fiscal realism,
- commercial partnerships,
- scientific exploration,
- technology pull and push,
- gradual build-up of capability,
- economic opportunity,
- architecture openness and resilience,
- global collaboration and leadership, and
- continuity of human space flight.

Mr. Bowersox commented that the principles should result in the sustainable program that NASA is working toward. In response to a question from Mr. Bowersox, Mr. Gerstenmaier explained that the first two principles had been modified from when they were initially presented to the Committee at its last meeting.

Mr. Gerstenmaier continued to describe the FY 2019 budget submit. It provides approximately \$9.2B for HEOMD to pursue Administration and NASA Exploration goals consistent with the National Space Council's (NSC) Space Policy soon approved by the President and the NASA Transition Authorization Act of 2017. It will enable NASA to continue to develop the Orion crew capsule, the SLS rocket, and Exploration Ground Systems (EGS). It also provides for developing the Gateway.

Working in parallel with the Science Mission Directorate (SMD), HEOMD is planning to develop a series of progressively more capable lunar missions to the surface of the Moon that will serve as a training ground to prepare for utilization of the Moon and later missions to Mars. NASA will use innovative acquisition approaches to enable U.S. commercial capabilities to be leveraged toward

human exploration of the lunar surface. In addition, NASA will include contributions of the International partners as appropriate. Mr. Gerstenmaier presented a Budget Structure Crosswalk chart, which illustrates how to compare the FY 2018 budget and the FY 2019 President's Budget Request with respect to changes in the Exploration account. He noted that the FY 2019 request includes a new account structure for human space exploration and technology programs to improve the alignment between funding and NASA's new strategic space exploration objectives. He reviewed a chart showing the HEOMD Program Financial Plan.

Mr. Gerstenmaier discussed Advanced Exploration Systems (AES) and presented a chart showing notional launches for the NASA Exploration Campaign. He described the Gateway. It will be assembled in orbit around the Moon by 2025. It can be used as a staging point in a variety of orbits for missions to the lunar surface and destinations in deep space. It will include four main capabilities: the Power and Propulsion Element (PPE), a small habitation module, an airlock to enable extra-vehicular activities (EVAs) and science operations, and logistics. The PPE will provide deep-space power and propulsion as well as a communication capability through a public-private partnership. The logistics will allow cargo deliveries to enable extended crew mission durations, science utilization, exploration technology demonstrations, and potential commercial utilization. NASA plans to launch the PPE in 2022 on a commercial launch vehicle. The other three capabilities will be launched on SLS, beginning in 2023.

Mr. Gerstenmaier explained that NASA is "learning how to do a human lunar lander again." HEOMD is accelerating work on life support systems to complete testing on the ISS by the end of FY 2024. The ISS will be used as a testbed for exploration technologies that include the next generation environmental control and life support system (ECLSS), a brine processor, a universal waste management system, a carbon dioxide (CO<sub>2</sub>) removal system, development of Saffire IV-VI to reduce risk associated with spacecraft fire safety, and the Bigelow Expandable Activity Module (BEAM).

Mr. Gerstenmaier described the Exploration System Development (Exploration or ESD) Program's progress on Orion, SLS, and EGS. He presented an integrated manifest showing tentative launch dates for: the Orion Ascent Abort-2 (AA-2) test article the first lunar flight test, Exploration Mission (EM)-1; the first lunar crewed flight, EM-2; and the second lunar crewed flight, EM-3. He reviewed the trajectories for EM-1 and EM-2. Mr. Gerstenmaier presented integrated mission milestone summary charts for both flights and noted that they are being worked concurrently. He noted that Orion's architecture and design support multiple exploration scenarios to enable deep-space, human exploration missions. Four Orion vehicles are in assembly and undergoing testing. He presented charts showing the Orion strategic schedule and its critical paths and reviewed the Orion schedule milestones. Mr. Gerstenmaier presented a graphic showing the evolution of SLS heavy lift launch capabilities. In the near term, SLS will use the Interim Cryogenic Propulsion Stage (ICPS) to deliver over 26 metric tons beyond LEO and toward the Moon in a trans-lunar injection (TLI). An Exploration Upper Stage (EUS) is being developed that will allow SLS to deliver more than 37 metric tons to TLI to significantly expand deep-space mission capability as early as the budget allows. Future advanced boosters will be able to deliver more than 45 metric tons to TLI. Mr. Gerstenmaier reviewed EM-1 schedule milestones for SLS and for EGS. He described EGS plans for FY 2018 and FY 2019.

Mr. Gerstenmaier discussed ISS research plans for FY 2018 and FY 2019. He described the commercial research capabilities available in the U.S. National Laboratory managed on the ISS by the Center for the Advancement of Science in Space (CASIS). He noted that there is increased interest in small, cube-like satellites. He described the Remote Manipulator Small-Satellite System (RM3S), which is a small satellite dispenser that has the capacity to deploy a large volume of nanosatellites within a single deployment cycle. The Brine Processing Assembly (BPA) should improve to over 90 percent the recovery of water from urine brine.

Mr. Gerstenmaier reviewed the CCP and Commercial Resupply Program plans for FY 2018 through FY 2019. The first CCP Post Certification Mission is planned for April 2019. The SpaceX Crew Dragon transportation system capsule uses the Space X Falcon 9 launch vehicle and employs parachutes for a water landing. The Boeing Starliner crew transportation system capsule uses the United Launch Alliance (ULA) Atlas 5 launch vehicle. It relies on a parachute and airbag system for hard surface or contingency water landings. Mr. Gerstenmaier noted that NASA has contracted with Russia to provide Soyuz seats to the ISS through Spring 2019. He described the FY 2018 and FY 2019 plans for Space Communications and Navigation (SCaN). He presented a chart showing the schedule and milestones for rocket propulsion testing. He explained that the Launch Services Program (LSP) provides management of NASA launch services contracts, launch mission assurance, and mission design and launch integration support. LSP enables the NASA Administrator to serve as the launch agent for the U.S. civil sector described in the National Space Transportation Policy.

Mr. Gerstenmaier concluded his presentation with a chart showing that NASA is leading future space exploration by:

- building a platform that will orbit the Moon,
- sending landers to the lunar surface in preparation for a human return,
- stimulating the LEO commercial space economy,
- developing technologies needed for exploration and resolving human health and performance challenges, and
- expanding U.S. leadership through partnerships with commercial industry and other nations.

Mr. Wayne Hale asked whether the Gateway remains necessary now that the focus is back on the Moon. Mr. Gerstenmaier explained that the best testbed for life support equipment is the ISS, rather than testing the equipment near the Moon. The ISS is scheduled to last until 2024. The Gateway architecture can be used in a sustainable way. Gateway can be used as a waypoint for vehicles coming from the Moon's surface; it enables operations beyond the Earth-Moon system without the alternative of going directly to the Moon's surface. Mr. Bowersox commented that Gateway contributes to getting to Mars, because it facilitates testing propulsion and radiation mitigation.

Dr. Leroy Chiao asked whether Gateway can replace the ISS after it is retired in 2024. Mr. Gerstenmaier responded that continued capability is needed in LEO. He stated, "you are not going to want your first space flight to be in the vicinity of the Moon." He explained that a small commercial capability in LEO is needed. He added that the new budget begins the discussion on

how to make the transition from the ISS and whether 2024 is the right time frame. Some work will transition to Gateway, and there will be a need for both in the future. Mr. Hale asked whether the Falcon 9 Heavy could be used without building the more expensive SLS. Mr. Gerstenmaier responded that the SLS would have a much heavier lift capability and that both vehicles will have a role in the future.

Mr. Bowersox commented that the current HEOMD organization has worked well over last few years and asked about the advantages for a reorganization. Mr. Gerstenmaier responded that there are many advantages for HEOMD and the STMD to remain as separate organizations, integrated as they are today. There are not many advantages to moving STMD into HEOMD. In response to a question from Ms. Shannon Bartell, Mr. Gerstenmaier stated that it would be very helpful to have an outside auditor assess the problems presented by NASA Procedural Requirement (NPR) 7120.

Mr. Bowersox thanked Mr. Gerstenmaier for his presentation.

### Exploration Systems Division

Mr. Bowersox introduced Mr. Bill Hill, Deputy AA, ESD, HEOMD, and Mr. Marshall Smith, Director, Cross-Program Systems Integration (CPSI), ESD, HEOMD. Mr. Hill reviewed the EM-1 and EM-2 Integrated Mission Milestone Summary (IMMS) charts. He explained that the European Space Agency (ESA) Service Module (ESM) remains on the EM-1 primary critical path. The Core Stage is on the EM-1 secondary critical path. There are approximately three months of schedule risk from each item. Mr. Hill noted that the ESM schedule has held steady over the last four months; he attributed that to the attention paid to the project by ESA leadership. He also noted that the recently approved FY 2018 budget now includes funding for a second mobile launch platform (MLP), making it unnecessary to modify the existing MLP. The EM-2 schedule will be adjusted to eliminate the 33 months that would have been needed to accomplish those modifications.

Mr. Smith reviewed the Systems Engineering & Integration (SE&I) Summary Schedule for EM-1. He explained that the primary, critical-path item on that schedule is integrated loads and guidance, navigation and control (GN&C). That item begins with completion of the Core Stage modal test at NASA's Stennis Space Center (SSC) followed by 10 months of loads and GN&C analysis, including mission certification testing with flight-specific parameters in the SLS System Integration Lab (SIL). Mr. Smith provided an overview on SE&I's top critical integrated issues:

- loads and GN&C;
- the Orion simulator;
- enterprise verification and validation (V&V);
- core-stage assembly, integration, and testing;
- green run testing;
- the ESM;
- vehicle assembly, integration, and test (AI&T);
- integrated software;
- pad stay time;
- fracture control;
- integrated trajectories;

- booster throat plug debris;
- payloads; and
- mobile launcher stress.

Mr. Smith discussed the CPIT's technical focus on:

- the ICPS umbilical loads,
- launch availability,
- communication uplink for the EM-2 EUS,
- Block 1B loads that exceed Orion design loads, and
- the Block 1B vehicle damper system location.

He described the building block approach for loads model V&V. Test-validated element and program structural dynamics models are used as building blocks to assemble integrated flight models. He presented slides showing the structural test articles (STAs) for the core-stage engine section, the core-stage liquid hydrogen tank, the core-stage intertank, and the core-stage liquid oxygen (LOX) tank. He described the ICPS integrated structural test for the Orion spacecraft adapter, the ICPS, and the launch-vehicle-to-stages adapter (LVSA). They withstood all limit, ultimate, and margin load cases with no signs of detrimental deformation, rupture, or collapse. Mr. Smith reviewed SLS STA testing. He presented charts on Orion structural qualification, the Orion testing schedule, and the EM-1 SE&I summary schedule.

Mr. Smith concluded his presentation with an overview on using the Best Model Estimate (BME) and Flight Dynamics Risk Assessment (FDRA) approach. The BME/FDRA approach develops a suite of potential modal testing results that allow easier assessment. Thousands of model dispersions are created from pre-test models. Each dispersion is compared to the modal test results to determine which one best matches the test. GN&C uses the BME flight models to run a stability assessment. The Orion and SLS element low-transformation matrixes corresponding to the pre-test models are used to perform a quick loads risk assessment. A final risk assessment will be presented at Flight Readiness Review (FRR).

Mr. Bowersox asked whether SLS test facilities could be used for commercial rocket development. Mr. Gerstenmaier explained that commercial companies do not do that type of testing. They rely strictly on analysis, because the size precludes using models for testing. Mr. Gerstenmaier added that NASA is learning from its testing that its models are good.

Mr. Bowersox thanked Mr. Hill and Mr. Smith for their presentations.

### Commercial Crew

Mr. Bowersox introduced Ms. Kathy Lueders, Manager, CCP, HEOMD, who briefed the Committee on the status and technical progress for the CCP Commercial Crew Transportation Capabilities (CCtCap) and Commercial Crew Integrated Capability (CCiCap) contracts.

Ms. Lueders advised the Committee that CCP has made significant progress over the last quarter. Mission planning and preparations are underway for eight CCP missions--four for Boeing and four for SpaceX. Both providers are making tangible progress toward flight tests and crewed missions



to the ISS. Boeing's uncrewed orbital flight test is scheduled for August 2018. SpaceX's uncrewed flight to ISS is also scheduled for August 2018. Boeing's crewed flight test is scheduled for November 2018. Space X's crewed flight to ISS is scheduled for December 2018. Both providers are performing critical test and verification events and making progress in the burn-down of key certification products. Ms. Lueders presented the CCtCap Combined Milestone Summary chart for FY17, fourth quarter. Mr. Gerald Smith asked whether SpaceX understands the magnitude of the paperwork and all the certifications that are required. Ms. Lueders responded that SpaceX has that experience from knowing what is needed to deliver cargo to the ISS. She added that "building all the paper products is tough for them, as well as for Boeing."

Ms. Lueders reviewed the CCP top risks. The top programmatic risks are inability to meet loss of crew (LOC) probabilities and the Department of Defense (DoD) search and rescue training schedule. The top safety risks are inability to meet LOC probabilities, aborting into sea states with unsafe rescue, and crew entry accelerations and space flight-associated neuro-ocular syndrome (SANS) exacerbations.

Ms. Lueders described SpaceX's progress towards developing the Dragon crew capsule, developing the Falcon 9 launch vehicle, conducting the in-flight abort test, finalizing the Flight Test Plan, and renovating Launch Complex (LC)-39A at NASA's Kennedy Space Center (KSC). She reviewed Boeing's accomplishments on the Spacecraft 3 Orbital Flight Test (OFT) vehicle, the Atlas V launch vehicle, and the Spacecraft 2 Crewed Flight Test (CFT) vehicle. Ms. Lueders explained that parachute deployment is one of the biggest problems. Dr. Pat Condon noted that 50 years ago, NASA had a lot of experience with parachutes. Ms. Lueders responded that the contractors are working through how to model parachutes and are getting ready to do water-landing tests.

Ms. Lueders presented a chart showing the Integrated Flight Test Readiness Review (FTRR) process. She explained that the process is a series of CCP and ISS program reviews that culminate in an integrated CCP Agency FTRR. Mr. Hale asked when design certification will be complete. Ms. Lueders responded that the post-certification flight test is a culminating milestone. Under the contract, there is a certification portion and a mission portion. All the requirements for flying crew safely are closed out prior to the first crewed flight test. Before crew fly, the CCP will make sure that the contractors meet the human rating requirements that are needed to fly crew safely. In response to a question from Mr. Bowersox, Ms. Lueders advised that the Certification of Flight Readiness (CoFR) statements would be signed at the readiness reviews.

Ms. Lueders reviewed Blue Origin's accomplishments under its Commercial Space Capabilities Collaboration (CSCC) Space Act Agreement (SAA) with NASA. She described technical exchanges and data exchanges under that SAA. Pursuant to the SAA, NASA meets with Blue Origin twice annually. She reviewed Sierra Nevada Corporation (SNC) accomplishments under its CCIcap SAA and noted that funding has been approved for a second flight test drop. NASA also meets with SNC semi-annually under its SAA. In response to a question from Mr. Smith, Mr. Lueders explained that the SAAs have been extended to provide for unfunded data exchanges. In response to a question from Dr. Condon, Ms. Lueders explained that the CCP uses the SAAs to support the companies' objectives incrementally without attempting to understand how that fits in with their business objectives. Mr. Phil McAllister noted that both companies have plans for crewed transportation.

Ms. Lueders stated that CCP continues to facilitate the development and certification of U.S. industry-based crew transportation systems. Boeing and SpaceX are meeting contractual milestones and maturing their designs. Both providers are making tangible progress toward flight tests and crewed missions to the ISS. CCP has robust and efficient processes for certification, including addressing waivers and deviations. Significant work remains ahead in preparation for flight. Mr. Bowersox noted that the schedules show both Boeing and SpaceX preparing for crewed launches by the end of 2018, and he asked whether that scheduling was “aggressive.” Ms. Lueders responded affirmatively, based on the hardware that is required. Mr. Bowersox commented “it is important to lean forward and try to make those schedules.” Ms. Lueders stated that CCP wants them to do it as fast as possible without sacrificing crew safety. She added, “We want to give them the time to do it right.”

Dr. Patricia Sanders noted that the Aerospace Safety Advisory Panel (ASAP) had reviewed the schedule risk and concluded that the CCP continues to do the right things. Mr. Hale dissented and noted that program managers make safety decisions every day based on schedule. He stated, “space flight is not safe—it is a risky business. If you want to make it perfectly safe you stay at home.” Dr. Sanders concurred and stated, “they are not making schedule-driven decisions to shortcut safety.” Mr. Hale responded, “it is a fine line.”

Mr. Bowersox commented that it is important to return crew launch capability to America, and it is exciting to see the CCP getting close to accomplishing that goal. He thanked Ms. Lueders for her presentation.

#### Space Life and Physical Sciences Research Applications Status

Mr. Bowersox introduced Dr. Craig Kundrot, Director, Space Life and Physical Sciences Research and Applications (SLPSRA) Division, HEOMD, who briefed the Committee on SLPSRA’s recent activities.

Dr. Kundrot presented a chart showing how the Division is organized. It has three programs: the Human Research Program (HRP), Space Biology, and Physical Sciences. He reviewed a chart showing the number of tasks and workforce for each program.

Dr. Kundrot described the development of ATLAS, which is intended to replace three racks of ISS exercise hardware and be used for deep-space exploration. It protects against bone loss, muscle loss, and cardiovascular inactivity. It can duplicate free weights and rowing; however, it cannot duplicate the effect of running on a treadmill. Mr. Bowersox commented that Russian doctors had informed him it is important to exercise in space by moving your legs in a walking fashion. Dr. Kundrot discussed crew performance after returning from space flight. Every returning crewmember exhibits vestibular, cerebellar, and sensorimotor decrements. Every crewmember experiences landing-related motion sickness. There is considerable variation between crewmembers’ performance. Strength is likely not a limiting factor because of current in-flight exercise countermeasures. Dr. Kundrot explained that emergency egress during or after a water landing will present a significant risk to astronaut safety.

Dr. Kundrot described recent experiments flown on the ISS. In Rodent Research-9, 20 mice were flown and returned live for dissection in the Principal Investigator's (PI's) laboratory. The dissection team isolated 43 tissues. The Advanced Colloids Experiment T6 studied the microscopic behavior of colloids in gels and creams, providing new insight into fundamental interactions that can improve product shelf life. Four patent applications pertaining to product development and shelf life have been filed because of that experiment. The Capillary Flow Experiments investigated capillary flows and phenomena in low gravity. The experiment obtained data related to fluids management systems, thermal control systems, and materials processing in the liquid state. Spinoffs from that research include a microgravity urine collection device patent, ISS coffee and espresso machines, a plant watering system, and more than 40 peer-reviewed publications and conference papers.

Dr. Kundrot reviewed several recommendations from the midterm assessment of implementation of the Decadal Survey on Life and Physical Science Research at NASA. Survey Recommendation 5-11 provides:

*"NASA should aggressively lead in the 46 research priorities for deep space exploration . . . to provide as much "pull" as possible . . . NASA should, for example, lead in the development of microgravity-adapted biological and physical systems, making maximum use of all available platforms, including the ISS, specifically for the science behind the design and implementation of microgravity-optimized operation."*

The SLPSRA Division agreed that the recommendation is a helpful prioritization to guide the allocation of SLPSRA resources.

Recommendation 5-12 provides:

*"The Committee recommends that a cautious approach be used when shifting the NASA research portfolio more toward those types of experiments necessary for deep space exploration, so as to maintain the benefits of important basic experiments, especially those uniquely enabled by ISS microgravity and already in progress, which may in the long term have the potential for major impacts in fundamental physical science."*

The SLPSRA Division agreed with the recommendation. Dr. Kundrot explained that part of the Division's mission is to pioneer scientific discovery for other government agencies, commercial companies, and international partners. Therefore, areas like fundamental physics are an important part of the SLPSRA portfolio. That research also helps develop the future commercial workforce and future generations of space technologies.

Recommendation 5-8 provides:

*"In order to maximize the implementation of the cable survey priorities within its constrained resources, NASA should continue to be mindful of the full range of platforms (including drop towers, aircraft, balloons, suborbital vehicles, and free-flyers) and terrestrial analogs and ground-based laboratories available for Decadal survey research."*

The SLPSRA Division agreed with the recommendation. Dr. Kundrot described the research platforms in current use and proposed for future use.

Dr. Kundrot discussed the President's Budget Request for FY 2019. The HRP budget remains unchanged at \$140 Million (M). The budget for Space Biology and Physical Sciences is now contained within the ISS Research budget line and is presumed unchanged at approximately \$80M. He described restructuring options for HEOMD and STMD and discussed the NASA Strategic Plan. Strategic Objective 1.2 calls for NASA to understand responses of physical and biological systems to space flight. Dr. Kundrot explained that the space flight environment stresses physical and biological systems in many ways, including microgravity and space radiation. Dr. Kundrot discussed the importance of having customers. Progress in achieving the strategic objective will be measured by the formulation of agreements between the research programs and the internal NASA customer for enabling exploration or external organizations for scientific discovery. He noted that there are now alternate space launch capabilities and a myriad of payload developers. He stated, "for \$40,000 you too can fly a CubeSat."

Dr. Kundrot described a recent Gateway workshop. SLPSRA was responsible for 46 of the 110 papers presented at the workshop. He explained that the Gateway has strong ties to the Decadal Survey, because it provides access to the deep-space radiation environment. He discussed the Microbiome of Built Environment (MoBE). He reviewed considerations raised by the science community about Gateway:

- internal and external payloads;
- limited volume;
- power;
- crew time;
- dormant periods;
- cold stowage;
- sample return; and
- desire for glovebox, microscopes, freezers, wetlab facilities remote operations, high-capacity data transmission, robotic tasking, and automation.

Dr. Kundrot discussed the SLPSRA Strategic Plan. The SLPSRA vision states "We lead the space life and physical sciences research community to enable space exploration and benefit life on Earth." The SLPSRA mission is twofold:

- Enable Exploration to expand the frontiers of knowledge, capability, and opportunity in space.
- Pioneer scientific discovery in and beyond LEO to drive advances in science, technology, and space exploration to enhance knowledge, education, innovation, and economic vitality.

Dr. Kundrot described SLPSRA's implementation principles:

- ensure scientific integrity,
- maximize open science,
- cultivate partnerships,
- use steppingstones,

- be an early adopter of new space flight platforms, and
- facilitate commercialization of space by making research available to commercial companies.

Ms. Nancy Ann Budden asked whether NASA's partner nations were sharing science results well. Dr. Kundrot responded affirmatively and added "on the whole there is a lot of good work; it can be improved." He noted that there are working groups that have existed for decades. NASA is partnering with the Russians' Joint Working Group. The International Space Life Sciences Working Group will be having its 54<sup>th</sup> meeting soon.

Mr. Bowersox thanked Dr. Kundrot for his presentation.

### Discussion and Recommendations

Mr. Bowersox reviewed the Committee's prior concerns on budget uncertainty, bureaucratic processes, concurrent reviews, launch rates, and shifting priorities. He stated that those concerns had been presented by him at the last NASA Advisory Council (NAC) meeting. At that meeting, the NAC approved the Committee's finding on NASA's Human Exploration Plans and the Committee's recommendation for an interactive link between the NAC and the NSC. The NSC has since established a user advisory group, and Gen. Lester Lyles, the NAC Chair, serves on the group. Dr. Condon noted that NASA had disagreed in part with the recommendation. Mr. Gerstenmaier explained that the reason was because NASA lacked authority to direct the NSC to implement the recommendation.

Mr. Bowersox reviewed the Committee's future work plan. Mr. Gerstenmaier expressed concern about the effect NPR 7120 has on an auditor's ability to monitor multi-decadal projects. Ms. Shannon Bartell suggested presenting that problem to the NAC.

The Committee discussed the ISS transition plan. Ms. Budden commented that recent flights and successes demonstrate that the ISS has continuing value and should remain in orbit longer than planned.

Dr. Condon expressed concern about the Committee prescribing the platform that NASA should use in performing its mission. He stated, "NASA should define the most appropriate platform to address its capability needs."

Mr. Hale advised that a long lead time is needed for deciding to extend the ISS. He stated "ISS is our toehold as a presence in space. The gap in launch capability has not served us well."

Mr. Bowersox asked about finding additional uses for SLS and Orion. Dr. Sanders advised that NASA should use SLS for what it does well and use commercial launch vehicles for other purposes. Mr. Lon Levin advised against ending the ISS until there is an alternative. Mr. Gerstenmaier noted that the budget indicates ISS funding will end in 2025. Mr. Bowersox commented that extending the ISS forever would inhibit commercial development. He added that there seems to be a need to extend ISS to 2028 for Exploration. He suggested encouraging HEOMD to identify the LEO capabilities required for Exploration and determine whether any commercial providers can supply those capabilities.

Mr. Levin advised “Don’t turn off one until we know it can be replaced.”

Dr. Sanders stated, “It is an international space station—the decision is not ours solely.”

The Committee discussed the CCP. Mr. Bowersox observed that the Program is making great progress and is working through very difficult issues.

Mr. Bob Sieck noted that the CCP is at the peak of testing hardware and stated, “They will transition from talking around the table to sitting with headsets on.”

Ms. Bartell commented that the technical authority system may be causing issues on timely paperwork for the commercial program. Mr. Gerstenmaier explained that it is “almost a perfect storm” of the paperwork coming in to the technical authorities for commercial, SLS, and Orion at the same time. He added that the paperwork shows up after hardware is developed and “is not a problem at the lower levels where there are enough people working.” He stated, “It will be a difficult process.” Dr. Condon commented, “It is encouraging to observe the level of enthusiasm and excitement within NASA about where NASA is headed right now.”

Mr. Bowersox thanked everyone for their comments.

### Adjourn

Dr. Siegel adjourned the committee meeting for the day at 5:00 p.m.

## ***Tuesday, March 27, 2018***

### Opening Remarks

Dr. Siegel reconvened the Committee meeting at 8:00 a.m. and welcomed everyone. She introduced Mr. Bowersox.

### Power and Propulsion Element Status

Mr. Bowersox introduced Dr. Michele M. Gates, Director, PPE, HEOMD, who discussed the status of the PPE for the Gateway. Dr. Gates noted that she had previously briefed the Committee on the advantages of solar electric propulsion (SEP) in cislunar space. She explained that the PPE is the first element in the cislunar Gateway concept. In addition to SEP, the PPE would host communications as well as command and control functions. Dr. Gates reviewed a chart showing the PPE near-term milestones that have been completed. The FY 2019 President’s Budget Request for the Power and Propulsion Element is \$ 327.9 M.

Dr. Gates described the approach to the PPE development. It leverages advanced SEP technologies developed and matured during the Asteroid Redirect Mission (ARM) activities. The first Gateway element capability is targeted for launch readiness in 2022. It will be developed through a public-private partnership. Dr. Gates reviewed PPE industry partnership studies that had been solicited

through a NextSTEP Broad Agency Announcement (BAA). The studies focused on examining differences between prior SEP mission concepts, expected industry capabilities, and potential needs supporting NASA's Gateway concept. She presented a chart listing 23 study topics and a graphic showing the five study participants.

Dr. Gates explained that NASA's PPE strategy is to stimulate and utilize U.S. commercial space industry while leveraging those same commercial capabilities through partnerships and future contracts to deliver NASA mission capabilities. The PPE provider is to perform a demonstration of the PPE to the set of joint industry partner/NASA-developed demonstration objectives. NASA currently envisions that the PPE will be fully owned and operated by the PPE developer through completion of a space flight demonstration lasting up to one year. After completion of the demonstration, NASA will have the option to acquire the PPE for potential future operational use on NASA missions. NASA's Glenn Research Center (GRC) will release a BAA seeking industry proposals. An Industry Day will be held after the draft BAA is released.

Dr. Gates presented a series of slides showing STMD progress in electric propulsion technology. She presented a chart showing PPE upcoming events.

In response to a question from Dr. Condon, Dr. Gates explained that magnetic shielding would be used to protect the PPE against erosion. Dr. Condon asked whether there would be component repair or replacement. Dr. Gates responded that there was no plan to have an *in-situ* repair or replacement capability in space; however, there would be a capability for refueling. Mr. Bowersox commented that an ability to replace thrusters would be very valuable. He added that on-orbit servicing is something commercial satellite providers are considering. In response to a question from Mr. Sieck, Dr. Gates explained that testing would be performed in thermal vacuum chambers at GRC and at NASA's Jet Propulsion Laboratory (JPL).

Mr. Bowersox thanked Dr. Gates for her presentation.

#### Future Human Exploration Planning and Lunar Orbital Platform-Gateway Concept Update

Dr. Siegel introduced Mr. Jason Crusan, Director, AES Division, HEOMD.

Mr. Crusan presented a graphic for the Lunar Exploration Campaign showing the transition from LEO to cislunar space to Mars. He discussed the NASA Exploration Campaign. It begins with an early science and technology initiative. CubeSats will be utilized because they are good at doing single measurements and for reducing risk. There will be a small commercial lander initiative. Private companies have asserted a preparedness to make landings on the Moon's surface beginning in 2019 to 2020. Indefinite Delivery/Indefinite Quantity (IDIQ) contracts will be used in a funded, risk-reduction activity to engage those companies to do individual landings. That will be followed by a mid-to-large lander initiative leading to a human rated lander. In response to a question from Mr. Levin, Mr. Crusan explained that the purpose of human rating is to obtain a high-reliability system. The traditional way to obtain high reliability is through redundancy; however, landers do not allow full redundancy. The strategy is for NASA and industry to learn how to provide reliability without redundancy for human rating. The budget has funds for two 500-kg class demonstration missions leading towards human-class landers; those will be developed jointly by NASA and industry because it is important for both to learn together.

Mr. Crusan reviewed a chart on the FY 2019 President's Proposed Budget for AES. The budget allocates \$504.2M for the Gateway, \$116.5M for Advanced Cislunar and Surface Capabilities (ACSC), and \$268.2M for Exploration Advanced Systems (EAS). The Gateway will be assembled in orbit around the Moon. It can be used as a staging point for missions to the lunar surface and to destinations in deep space. ACSC will establish U.S. preeminence to, around, and on the Moon by leveraging initial flights of the SLS, Orion, and elements of the Gateway. EAS will design, develop, and demonstrate exploration habitation capabilities and technologies to reduce risk, lower lifecycle costs, and validate operational concepts needed for future deep space habitation elements, including those on the Gateway.

Mr. Crusan discussed Gateway functionality. It will be based on two assumptions. First, the Gateway should provide ability to support multiple NASA, U.S., commercial, and international partner objectives in cislunar space and beyond. Second, the Gateway should be designed for deep space environments that support a crew of four for a minimum of 30 days and support staging of other assets, including landers. The current emphasis is on defining early elements and analyzing trade-offs for functional allocations. There will be a PPE, habitation, logistics, and an airlock. Future feasibility trade analysis will cover partner-provided elements, lunar landers, and preparing for destinations beyond the Moon, including Mars transportation.

Mr. Crusan presented charts showing organization and policy trees for flow down on documentation. The documents describe what is needed for exploration systems certification, what will be built, what capabilities are needed for systems and crew, how systems will be used, and when the capabilities and resources will be needed. Mr. Bowersox asked whether these were "living documents," and Mr. Crusan responded affirmatively. He described process for maturing the documents.

Mr. Crusan discussed draft, deep-space interoperability system standards. NASA, in collaboration with ISS partners, have developed a draft set of those standards in seven areas: avionics, communications, ECLSS, power, rendezvous, robotics, and thermal. The draft standards have been released for public comment. The goal is to enable industry and international entities to independently develop systems and elements for deep space that will be compatible aboard any spacecraft, irrelevant of the spacecraft developer. There is a website for those comments: [www.internationaldeepspacestandards.com](http://www.internationaldeepspacestandards.com). Mr. Gerstenmaier described one example for a standard: having the same pressure for all modules, which would eliminate the need for an airlock between two vessels. Mr. Levin commented that it is "good news on the evolution and understanding for space flight that there is some common understanding on how to do things." Mr. Gerstenmaier explained that the concept was used for the radio spectrum, USB ports for pinouts, and the ISS docking system. It doesn't tell people how to build the hardware. Ms. Budden commented that it gives flexibility for cooperation from new international, industry, and military partners. Mr. Gerstenmaier noted that the website is intentionally not .gov, but rather .com, in order to work more easily with the International Partners.

That

Mr. Crusan presented a chart showing the Gateway top-level schedule. He discussed Gateway core functionality. The PPE is targeted for launch readiness in 2022 and will provide a space flight demonstration of advanced SEP spacecraft for industry and NASA objectives, developed through a public-private partnership. The habitation capability provides habitable volume and short-



duration life support functions for crew in cislunar space. It will have docking ports to allow for attachment to the PPE, other Gateway elements, and visiting vehicles. It will have attachment points for external robotics, external science, and rendezvous sensors. The airlock will provide a capability to enable astronaut EVAs. The EVAs are expected to be for emergency purposes only and not for maintenance. Logistics would be used to deliver cargo to enable extended crew mission durations, science utilization, exploration technology demonstrations, potential commercial utilization, and other supplies. Mr. Crusan described Gateway concept investigations currently underway with five industry partners. Each is developing a full-scale habitat prototype for ground testing. In response to a question from Mrs. Ruth Gardner, Mr. Crusan described how “firewalls” are used to protect each vendor’s intellectual property. The best ideas will be chosen and used to develop a final set of capabilities for the final flight systems. In response to a question from Mr. Levin, Mr. Crusan explained that the vendors can choose to work with their own international industry partners. Mr. Bowersox asked whether two different Gateways could be developed, and Mr. Crusan responded that there could be two or more habitation elements. But not likely two Gateways Ms. Bartell commented that there could be multiple Gateways if private industry wanted to put them up and see who would use them. Mr. Gerstenmaier explained that the question is whether they could develop revenue for those operations and that it would be “a stretch” to see sufficient revenue generation in cislunar space.

Mr. Crusan described the Gateway Science Workshop recently conducted in Denver, Colorado. The workshop was sponsored by HEOMD and SMD to engage the science community with respect to the science potential for the Gateway and to identify resources required to facilitate various scientific investigations. There were over 300 attendees from government, academia, and industry. He discussed what was learned at the workshop. Science utilization would be extremely constrained without an external robotic arm. The Gateway offers unique opportunities for Earth, heliophysics, astrophysics, and fundamental physics investigations. Externally mounted equipment could collect samples and provide important science about cometary material, solar composition, interstellar particles, and near-Earth objects. The radiation environment could provide important tests of the effects of radiation on biological organisms.

Ms. Bartell expressed concern that too much science could drive up operational costs and distract attention from the basic concept for the Gateway, which is to be a node for further exploration. Dr. Sanders expressed concern about losing focus on learning what is needed for space exploration.

Mr. Bowersox thanked Mr. Crusan for his presentation.

### Discussion

The Committee discussed tentative findings, concerns, observations, and recommendations. Ms. Budden suggested that the Committee express support for the trend in larger budgets.

Mr. Levin commented that he was impressed with the collective maturity shown in recognizing that after 50 years, NASA knows enough to establish standards. Mr. Bowersox described it as leading in a different way—orchestrating, rather than prescribing.

### Global Exploration Roadmap

Mr. Bowersox introduced Ms. Kathy Laurini, Senior Advisor, Exploration and Space Operations, HEOMD. Ms. Laurini briefed the Committee on the Global Exploration Roadmap (GER). The GER is a nonbinding document produced by the International Space Exploration Coordination Group (ISECG). NASA and 14 other space agencies participate in the ISECG to share information and work together to develop products that inform individual agency efforts and decisions with the goal of strengthening individual agency exploration programs and the collective effort. She noted that China and India also participate to a limited extent. Ms. Laurini, as NASA's representative, is the current ISECG chair and will be succeeded by a representative from the Japanese Aerospace Exploration Agency (JAXA).

The GER is a common roadmap which respects policies and plans of participating agencies. It begins with the ISS and expands human presence to the vicinity of the Moon and the lunar surface, leading to Mars orbital missions, and humans on the Martian surface. The common goals and objectives of participating agencies are to expand human presence into the solar system, understand humanity's place in the universe, engage the public, stimulate economic prosperity, and foster international cooperation. The GER contains a Mission Scenario that paints a picture of human and robotic exploration at the mission level, showing planned human and robotic missions in the next decade, as well as conceptual human missions that could follow. The Mission Scenario contains a high-level, human lunar exploration scenario for informing technology and conceptual study investments.

Ms. Laurini presented a chart showing a conceptual architecture for human lunar exploration. The architecture demonstrates a limited number of human lunar missions can accomplish high priority science objectives while maintaining a focus on demonstrating capabilities and technologies which will be needed for future Mars missions. She explained the human lunar lander architecture under study by JAXA, ESA, and the Canadian Space Agency (CSA). She explained that the ISS partner agencies are interested in playing significant roles; however, their budgets today do not match their ambitions. One problem, she noted, is that there has not been stability in the U.S. Administration policy related to exploration. If the U.S. goes to the Moon, the other agencies do not want to be left behind. Mr. Smith asked about the international partners' position on extending ISS beyond 2024. Ms. Laurini responded that the international partners see the ISS as a large investment and see a strong need for it to be continued. All the partners want to continue research in LEO and believe that a future LEO platform will be necessary. Some partners think it is important to transition to a commercial platform, while other partners are more skeptical and see the need for more government involvement.

Ms. Laurini discussed near-term opportunities for coordination and cooperation. Significant resources are being expended around the world to prepare for human space exploration. Space agencies want to know the other partner agencies' priorities and plans. They seek opportunities to leverage investments in exploration through international cooperation. The GER reflects space agency discussion on private sector space exploration initiatives, *in situ* research utilization (ISRU) at the lunar poles, advanced technologies, and analog activities. It demonstrates support for government and private sector partnerships develop space capabilities and enable commercial services, including cargo to the Gateway, communication, and delivering instruments and logistics to the lunar surface and Mars.

Ms. Laurini discussed ISRU at the lunar poles and presented a chart showing lunar missions currently planned by various space agencies. She reviewed a chart on critical technologies needed to enable and enhance human exploration. Critical technologies have been identified and a gap assessment is underway. She explained that lunar exploration will provide an opportunity to drive technologies needed for Mars.

Ms. Laurini described the recently held International Space Exploration Forum (ISEF). Its purpose is to enrich government-level understanding of the importance of space exploration for the benefit of humankind and further advance international cooperation on space exploration through non-binding, high-level policy dialogue. It produced three products: a joint statement, the Tokyo Principles for International Space Exploration, and ISEF Terms of Reference. The products are available at [www.isef2.jp](http://www.isef2.jp).

Ms. Laurini explained that the GER will serve as a tool to help national space agencies collaboratively prepare for future human space exploration missions and partnerships. An innovative and sustainable program of exploration needs international partners. Growing capability and interest from the private sector indicates a future that involves collaboration with private entities pursuing their own goals and objectives. Ms. Laurini concluded her presentation by noting that NASA's international partner space agencies want to be important stakeholders from the beginning of exploration beyond LEO. She asserted that it is important that they are such stakeholders.

Mr. Bowersox commented that it is great that NASA's efforts are syncing up with what the international partners want to do. He thanked Ms. Laurini for her presentation.

#### ISS Update, Accomplishments, and Future

Mr. Bowersox introduced Ms. Robyn Gatens, ISS Deputy Director, HEOMD, who briefed the Committee on the status of the ISS, its accomplishments, and its future.

Ms. Gatens provided an overview of the flight plan for ISS Increment 55/56. She described three upcoming EVAs. She presented a slide showing the crew for Increment 55.

Ms. Gatens described Exploration research and technology highlights. She explained that a new Agency priority goal was released with the FY 2019 President's Proposed Budget. The goal is to use the ISS as a testbed to demonstrate the critical systems necessary for long-duration missions. The goal focuses on Exploration-enabling demonstrations to be conducted on the ISS and includes demonstrations funded by ISS, AES, HRP, and Orion. Ms. Gatens presented a list of the currently planned demonstrations. She reviewed a slide on the ISS Exploration Technology Demonstration Fly-Off Plan. In response to a question from Mr. Levin, Ms. Gatens explained that the ISS is a better platform for the demonstrations than the Gateway. She added that the intention is to continue testing the ECLSS on another LEO platform after the ISS transition. Mr. Bowersox asked about the goal for the successful ECLSS run time. Ms. Gatens responded that there is a "system of one" that will be tested for three years. Mr. Smith advised "if you have just one, you want to have a fleet leader beyond three years."

Ms. Gatens described selected featured Exploration technology and investigations:

- Aerosol Sampling Experiment;
- Thermal Amine Scrubber;
- *In Situ* Bioanalyzer;
- Detrimental Effects of Long-Duration Space Flight on Human Wayfinding; and
- Fluid Shifts Before, During, and After Prolonged Space Flight and Their Association with Intracranial Pressure and Visual Impairment.

She reviewed a chart showing the HRP path to risk reduction. The top risks concern space radiation exposure.

Ms. Gatens presented charts on crew time utilization for Increment 53/54 and Increment 55/56. She reviewed ISS research statistics. There were 184 investigations conducted during Increment 55/56; 85 were NASA/U.S.-led and 99 were international-led. The total number of investigations during the ISS lifetime is estimated to be 2566, which have resulted in more than 1400 scientific results publications. Over 103 countries have participated in ISS research and education activities, with Mongolia and Singapore being the two most recently added to the list.

Ms. Gatens reviewed highlights for the ISS National Laboratory and CASIS. She presented a chart summarizing the CASIS FY 2017 Annual Report. She noted that over 70 percent of CASIS' 45 FY 2017 projects came from new-to-space customers and over 75 percent were education projects involving commercial sponsorship. More than \$6M was awarded by CASIS in FY 2017 to support those projects and related programs. Ms. Gatens presented slides showing the logos for all the CASIS implementation partners. She reviewed the National Laboratory results. Proctor & Gamble research on colloids correlated the microscopic behavior of complex fluids with the macroscopic properties of commercial products. The work related to improving product shelf life and inspired four patents. A new, single-board cloud computer was developed by Business Integra Technology Solutions as part of a CASIS project. The Material International Space Station Flight Facility (MISSE-FF), a platform to be launched on SpaceX-14, was developed by Alpha Space to test materials, coatings, and components in the harsh space environment. In response to a question from Mr. Levin, Ms. Gatens responded that more users are willing to pay a portion of the cost for doing research on the ISS. She stated, "It takes a while to establish a commercial market to the point where NASA is one of many customers." Mr. Gerstenmaier explained that the purpose of CASIS was to identify a community not traditionally using space and to encourage that community to find uses for space. It is up to those companies to figure out how to generate revenue. He stated, "We haven't reached the tipping point ... we underestimated the time it would take to get there."

Ms. Gatens discussed the ISS operational status. She presented a chart showing the actual hours of crew research time, by sponsor, for Increment 53/54 and noted it was fewer than the planned hours. She described recently completed and upcoming U.S. EVAs. She reviewed a chart showing the total consumables on board the ISS. Ms. Gatens described the recent successful Orbital-ATK (OA)-8 and SpaceX-13 missions. She reviewed the status for upcoming OA-9 and SpaceX-14 missions. She presented a chart on the status of Commercial Resupply Services (CRS)-2 missions that are planned for launch beginning in 2019. There will be three CRS-2 providers: OA, SpaceX, and SNC.

Ms. Gatens discussed the ISS transition. The NASA Transition Authorization Act of 2017 directed NASA to develop a plan to transition ISS from the current regime that relies heavily on NASA sponsorship to a regime where NASA could be one of many customers of a LEO, non-governmental human space flight enterprise. There are eight key principles for a strategy for the future of ISS and LEO:

- Provide continuity among NASA's LEO, deep-space exploration, and development and research activities and missions toward expanding human presence into the solar system.
- Expand U.S. human space flight leadership in LEO and deep-space exploration, including continuity of the relationship with current ISS international partners.
- Increase platform options in LEO to enable more ISS transition pathways, security through redundant capability in the event of ISS failure, and industrial capability that can support NASA's deep-space exploration needs.
- Spur vibrant commercial activity in LEO.
- Maintain critical human space flight knowledge and expertise within the Government in areas such as astronaut health and performance, life support, safety, and critical operational ground and crew experience.
- Continue to return benefits to humanity through government-sponsored basic and applied on-orbit research.
- Continue government-sponsored access to LEO research facilities that enable other government agencies, academia, and private industry to increase U.S. industrial competitiveness and provide goods and services to U.S. citizens.
- Continue to reduce the Government's long-term costs through private industry partnerships and competitive acquisition strategies.

In response to a question from Mr. Bowersox, Ms. Gatens explained that the principles have been discussed with the Office of Management and Budget (OMB) and the NSC. Mr. Gerstenmaier added that the plan will be final when it is made public. The NSC Executive Secretary will review the plan and provide comments. Dr. Sanders commented that Congress, not the NSC, imposed the requirement for the transition plan.

Ms. Gatens discussed the ISS Transition Strategy. It has two parts. One part is to begin a step-wise transition of ISS operations from a government-directed activity to a model where private industry is responsible for planning how to meet and execute NASA's requirements. NASA would continue to maintain leadership and governing responsibilities for astronaut safety and the high-risk exploration systems. The other part is to use a solicitation to obtain information from industry on the development and operation of private on-orbit modules, platforms, and other capabilities that NASA could use to meet its long-term LEO requirements that are consistent with the ISS Transition Principles.

Ms. Gatens described NASA's expected future needs in LEO. They are:

- continued partnership with NASA's current ISS international partners and possible new international and domestic participants;
- regular LEO crewed operations, including short and long durations;
- long-term technology/systems development and demonstrations;

- space life and physical sciences basic and applied research at current levels and capabilities;
- National Laboratory-based research and technology development; and
- opportunities for astrophysics, space, and Earth science research.

Those needs could be met with modules or platforms that do not require a new vehicle, and some needs could be met with platforms as complex as the ISS. In the near term, NASA plans to solicit inputs from industry on what LEO capabilities industry wants to provide and the resources needed so that NASA could become one of many customers. An ISS commercial use policy is under development to allow private industry to use spare ISS resources for commercial, for-profit activities. In response to a question from Mr. Levin, Ms. Gatens responded that a private platform is one of the services that NASA could purchase from private enterprise. It would have to be a crewed platform, rather than a crew-tended platform, because ECLSS testing requires crew breathing. Mr. Bowersox commented that it would be much more expensive to do the testing on the Gateway.

Mr. Bowersox thanked Ms. Gatens for her presentation.

#### Public Comments

Mr. Bowersox invited comments from the public. There were no public comments.

#### Discussion and Recommendations

Mr. Bowersox invited Committee members to suggest findings, recommendations, observations and concerns. Dr. Siegel noted that the NAC must review all findings and recommendations. Mr. Bowersox explained that the Committee maintains a concerns list to keep track of its issues, and that list does not require NAC approval. He reiterated that all findings and recommendations, even those intended just for the HEOMD AA, must be approved by the NAC.

The Committee discussed changes to the list of concerns and proposed recommendations. Some members expressed concern over the potential for an HEOMD reorganization. Dr. Sanders noted that direction had been given for the reorganization. Mr. Levin expressed concern about "SLS being a target." The Committee discussed NASA's governance structure and NPR 7120. With respect to the GER, Ms. Bartell noted that it gives no direction and serves only as a coordination and consensus-building tool. Mr. Bowersox commented that it shows that all the partners want to go to the Moon. Dr. Sanders explained that NASA would not get funding to do everything; a mechanism is needed to bring the other national space agencies into the process. Mr. Hale commented "it is not clear whether bringing on international partners reduces costs." Ms. Budden noted that while there is no customer for the product, it builds goodwill among the international partners and may help them get funding from their own countries. Dr. Siegel commented that the GER shows where there are "holes" in the program and provides an opportunity to the international partners to determine where they are needed and how they can participate. The Committee discussed international standards for space exploration. Mr. Smith suggested that NASA should establish a "lead-the-fleet goal" for ECLSS.

After further discussion, the Committee approved the following: Recommendation for HEOMD AA

**TITLE: Metrics for ISS Transition and Fleet Leader Approach for Critical Exploration Systems**

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

**Major reasons for proposing the recommendation:** NASA has set forth a very clear set of principles to guide its ISS transition plan for 2024 and beyond. In addition to these principles, it would be helpful for HEOMD to formulate metrics to guide the transition. Some suggested metrics would be the cost of alternative platforms, cost of conducting exploration systems development without access to low earth orbit, the minimum annual amount of orbital time required for crew preparation and training, and the amount of running time needed on exploration systems in low earth orbit before those systems could be certified for a trip to Mars. In particular it would be helpful to consider specific run time requirements for the critical systems that must be tested prior to a Mars transit such as life support, propulsion and avionics. It may even be appropriate to consider a fleet leader continuous test program for critical systems, where there is always a test platform that has more run time than the critical systems to be used aboard a reusable Mars transport vehicle.

**Consequences of no action on the proposed recommendation:** NASA will lose opportunities to clearly communicate the status of ISS transition criteria.

HEO Committee Observations:

- NASA has set forth a very clear set of principles to guide its ISS transition plan for 2024 and beyond. A set of metrics to accompany these principles and guide the progress of ISS transition would be very useful.
- The latest policy directive, and the recently approved 2018 NASA budget, show support for NASA's sustainable approach for human exploration.
- HEOMD's approach to leadership of future human exploration efforts in cislunar space relies more on communication and coordination of international efforts, technical standards and opportunities for involvement of commercial and international partners than on direction and prescriptive definition of individual contributions. The approach being used by HEOMD and NASA management seems very reasonable to the HEO Committee when considering the maturity level and capabilities of NASA's international and commercial partners.
- Audits and program assessments optimized for discreet missions which are used by outside organizations to review multi-decadal capability development programs with long operating lives and multiple individual missions such as ISS, SLS, or Orion may result in confusing results and conclusions that are not useful. It could be beneficial for NASA to take a look at different program evaluation products for multi-decadal capability development efforts.
- The approach and flexibility displayed by NASA in its commercial cargo program is resulting in the provision of essential services at a cost lower than previously possible. Whenever appropriate, NASA's other human exploration programs should be allowed to take advantage of the flexibility which has made the ISS commercial cargo delivery effort so successful. For example, allowing the SLS and Orion programs additional programmatic flexibility could be helpful as they continue to evaluate options for increased flight rate.

HEO committee concerns:

- As the Commercial Crew Program, SLS and Orion finish their development phases and transition toward operations, NASA's approach to program governance may unnecessarily slow the resolution of critical issues as they make their way through the programs and independent technical authorities for final resolution.



- The committee believes that the first crewed launch of the commercial crew program vehicles is very likely to occur within the next 8 to 24 months, and that NASA has adequate options to continue work on ISS throughout this period. If operational availability of commercial crew vehicles for station crew rotation is delayed beyond 18 months, the capability to do exploration systems development and science research aboard ISS may be impacted. US crew presence aboard ISS could be lost if availability of commercial transportation to ISS is delayed beyond about 24 months. The programs are continuing to look for ways to mitigate these impacts. An additional three months of margin was gained by the program since our last NAC review.
- Low SLS and Orion Launch rate pose future risks for proficiency of the operations team and reduce program resilience in the event of mission failure.
- Shifting priorities may result in the reduction of government funding for the ISS before a viable U.S. commercial follow-on capability is established. This capability is critical to allow NASA continued access to low Earth orbit for research, deep space exploration system testing, and other applications that may arise.
- The current HEOMD organization is working well due to its strong management team and also due to the synergy that comes from having exploration development and operations in the same mission directorate. Efforts to reorganize HEOMD at this time could increase the risk level of NASA's human exploration programs, especially considering the large amount of critical engineering work that must be completed prior to the first launches of the Commercial Crew vehicles, SLS and Orion.
- Future Special Topics:
  - International Participation in future human exploration \*\*\*
  - ISS after 2024 and ISS commercialization efforts \*\*\*
  - Deep space telescopes and possible servicing missions
  - Planetary Protection
  - Program decision making approach and independent technical authorities
  - Exploration EVA Capability
  - HEO External Review Summary
  - SLS and Orion activities to increase launch rate
  - Mars Transport Maintenance, Parts Commonality and Redundancy Strategy

\*\*\* Discussed at this meeting – March 2018

Mr. Bowersox thanked the Committee for its participation. He and Dr. Siegel also thanked the committee staff, Ms. Renee Pullen and Ms. Eracenia Kennedy, for their support.

Adjourn Public Session

Dr. Siegel adjourned the meeting at 2:30 p.m.

**NASA ADVISORY COUNCIL  
Human Exploration and Operations Committee  
MEETING  
NASA Headquarters  
Glennan Conference Center, Room 1Q39  
Washington, DC 20546**

**AGENDA**

March 26

NAC HEO COMMITTEE PUBLIC MEETING

11:00- 11:05	Call to Order, Welcome & Opening Remarks	Mr. Ken Bowersox & Dr. Bette Siegel
11:05 – 12:00	Human Exploration and Operations Overview	Mr. Bill Gerstenmaier
12:00- 1:00	<i>Lunch</i>	
1:00- 2:00	Exploration Systems Division	Mr. Bill Hill
2:00 – 3:00	Commercial Crew	Ms. Kathy Lueders
3:00-4:00	Space Life Physical Sciences Research Applications Status (SLPSRA)	Dr. Craig Kundrot
4:00-4:15	<i>Break</i>	
4:15- 5:30	Discussion and Recommendations	
5:30	<i>Adjourn</i>	

March 27, 2015

NAC HEO COMMITTEE PUBLIC MEETING

8:00 – 8:05	Opening Remarks	Dr. Bette Siegel / Mr. Ken Bowersox
8:05 – 9:00	Power Propulsion Element Status	Dr. Michele Gates
9:00- 10:00	Future Human Exploration Planning Deep Space Gateway Concept Update – Including Latest Science Workshop Summary	Mr. Jason Crusan
10:00-10:15	<b><i>Break</i></b>	
10:30-11:30	Global Exploration Roadmap	Ms. Kathy Laurini
11:30 – 12:30	ISS update, accomplishments and future	Ms. Robyn Gatens
12:30 - 1:30	<b><i>Lunch</i></b>	
1:30-1:35	Public comments	
1:35-2:30	Discussion and Recommendations	
2:30 pm	<b><i>Adjourn</i></b>	

**Human Exploration and Operations Committee Membership  
March 2018**

Mr. Ken Bowersox, <i>Chair</i>	Former NASA astronaut and retired U.S. Navy Captain
Dr. Bette Siegel	NASA Headquarters <i>Executive Secretary</i>
Ms. Shannon Bartell	Former Director of Safety & Mission Assurance, KSC
Ms. Nancy Ann Budden	Director for Special Operations Technology, Office of the Secretary of Defense
Dr. Leroy Chiao	Former NASA Astronaut and ISS Commander
Dr. Stephen “Pat” Condon	Aerospace Consultant, former Commander of the Ogden Air Logistics Center, the Arnold Engineering Development Center, and the Air Force Armament Laboratory
Mr. Joseph Cuzzupoli	Former Assistant Apollo Program Manager, Rockwell, and manager of the Space Shuttle Orbiter Project
Ms. Ruth Gardner	Technical Deputy Director, Engineering and Technology Directorate, Kennedy Space Center
Mr. Tommy Holloway	Former Space Shuttle and ISS Program Manager
Mr. Lon Levin	President, SkySevenVentures
Dr. David E. Longnecker	Director, Health Care Affairs, Association of American Medical Colleges (AAMC), member of the National Academy of Sciences Institute of Medicine (IOM)
Mr. Michael Lopez-Alegria	Former NASA astronaut and retired U.S. Navy Captain, President of the Commercial Spaceflight Federation
Mr. Bob Sieck	Former Space Shuttle Launch Director
Mr. Gerald Smith	Former Deputy Director, Stennis Space Center
Mr. James Voss	Former NASA astronaut and retired U.S. Army Colonel, Scholar in Residence, Department of Aerospace Engineering Sciences, University of Colorado, Boulder

**Human Exploration and Operations Committee  
NASA Headquarters  
Glennan Conference Center  
Washington, DC**

**March 26-27, 2018**

**MEETING ATTENDEES**

*HEO Committee Members:*

Bowersox, Kenneth, <i>Chair</i>	Aerospace Consultant
Siegel, Bette, <i>Executive Secretary</i>	NASA Headquarters
Bartell, Shannon	Aerospace Consultant
Budden, Nancy Ann	Office of the Secretary of Defense
Chiao, Leroy	Aerospace Consultant
Condon, Stephen "Pat"	Aerospace Consultant
Gardner, Ruth	Kennedy Space Center
Holloway, Tommy (via telecon)	Aerospace Consultant
Levin, Lon	SkySevenVentures
Lopez-Alegria, Michael	Commercial Spaceflight Federation
Sieck, Robert	Aerospace Consultant
Smith, Gerald	Aerospace Consultant
Voss, James	University of Colorado, Boulder

*NASA Attendees:*

Baldwin, Philip	NASA Headquarters
Carpenter, Brad	NASA Headquarters
Cox, Christie	NASA Headquarters
Crusan, Jason	NASA Headquarters
Curie, Mike	NASA Headquarters
Favors, Jamie	NASA Headquarters
Fincke, E.M.	NASA/JSC
Finley, Patrick	NASA Headquarters
Gatens, Robyn	NASA Headquarters
Gunderson, Bristol	NASA Headquarters
Gunn-Golyin, Anna	NASA Headquarters
Herrmann, Nicole	NASA Headquarters
Hudiburg, John	NASA Headquarters
Kundrot, Craig	NASA Headquarters
Laurini, Kathy	NASA Headquarters
Lueders, Kathy	NASA/KSC
McAlister, Phil	NASA Headquarters
McKay, Meredith	NASA Headquarters
Mumford, Toni	NASA Headquarters
Pullen, Renee	NASA Headquarters

Smith, Marshall	NASA Headquarters
Womer, Cheryl	NASA Headquarters

*Other Attendees:*

Barco, Juan	FSU
Hale, Wayne	NASA Advisory Council, member
Karanian, Linda	Aerojet Rocketdyne
Rockart, Richard	Stellar Solutions
Sanders, Patricia	Aerospace Safety Advisory Panel, chair

*Telecon Attendees:*

Aaron Oesterle	Polispace
Adam Schlessinger	Nasa JFC
Alicia Brown	
Amanda Moore	
Amy Svitak	
Andrea Riley	Nasa HQ
Andrew Rechenberg	
Andy Pasztor	
Anna Wieger	Nasa
Aravind Reddy	
Barbara Vellon	
Bill Harwood	
Bill Hill	Nasa HQ
Bill Peterson	Bill Peterson LLC
Brad Bailey	Nasa Sservi
Brent Jett	Private
Brian Card	Nasa
Casey Dreyer	
Cheryl	Nasa
Chris Gilbert	PE Consult
Chris Moore	
Clinton Giles	Casis
Christopher Giuliatti	
Dan Vergano	Buzzfeed News
Daniel Lentz	
David Crane	
David Eisenman	
David Gunn	
Darrell Brancome	Nasa
Deann Reilly	The Boeing Company
Denise Varga	Power & Propulsion Element
Desarea	Nasa HQ
Desire	Nasa HQ
Doug Craig	Nasa HQ
Doug Gauge	

Eric Berger	
Eddie	Nasa
Eisha Brown	Commerce Committee
Elsie Weigel	Nasa
Erika Vick	Nasa
Garry Burdick	JPL
Gene Fujikawa	Nasa
Helen Grandt	Nasa Office of Chief Science
James Dean	FL Today
Jeff Foust	Space News
Jennifer Read	JSC
Jennifer Troxell	Nasa
John Connolly	
John Hanson	Nasa
John McManamen	
John Rmmell	
Jose Ramos	
Katie Bogg	
Keith Cowing	
Kendra Riley	Nasa HQ
Kevin Soley	
Kim Esf	Nasa
Kiersten White	
Kristen VanWychen	
Kristina Gibbs	Nasa
Ladonna Miller	
L. Condes	Nasa
Loren Grush	
Lynn Loewy	
Marc Selinger	
Marchel Holle	
Marcia Smith	Space Policy On Line.com
Margaret Race	Seti Institute
Marguerite Broadwell	
Mark Brumfield	GSFC
Mary Ann Chevalier	
Mary Faller	
Mary Lynn Dittmar	
Michael Smiles	
Michael Barrett	Nasa
Nicholas	
Michael Roberts	Basis
OMB	OMB
Pat Troutman	Nasa
Patricia Soloveichik	
Patrick	Nasa



Paul Muri	
Phil Putter	
Philip Sloss	Nasaspaceflight.com
Rebecca Regan	
Renee Leck	
Richard McKinney	
Rick Irving	Nasa
R.J. Valenga	
Robert Delay	
Robert Giannini	
Ron Ticker	
Sandra Graham	
Ryan Lien	Nasa
Sam Black	Senate Commerce Committee
Sean Fuller	Nasa
Stacey Dreyer	
Stephen Clark	Space Flight Now
Sue Lieberts	
Victor Sparrow	
Tracy	Nasa KSC
Walter Schneider	Nasa

**Human Exploration and Operations Committee  
NASA Headquarters  
Washington, DC  
March 26-27, 2018**

**LIST OF PRESENTATION MATERIAL<sup>1</sup>**

- 1) Human Exploration and Operations Mission Directorate – Budget Status for NASA Advisory Council, Human Exploration and Operations Committee [Gerstenmaier]
- 2) Human Exploration and Operations – Advanced Exploration Systems [Gerstenmaier]
- 3) Human Exploration and Operations – Exploration System Development [Gerstenmaier]
- 4) Human Exploration and Operations – International Space Station [Gerstenmaier]
- 5) Human Exploration and Operations – Space Transportation [Gerstenmaier]
- 6) Human Exploration and Operations – Space Flight Support [Gerstenmaier]
- 7) Deep Space Exploration Systems [Hill, Smith]
- 8) Commercial Crew Program Status [Lueders]
- 9) Space Life and Physical Sciences Research and Applications Division [Kundrot]
- 10) Status of Power and Propulsion Element for Lunar Orbital Platform-Gateway [Gates]
- 11) Future Human Exploration Planning: Lunar Orbital Platform-Gateway and Science Workshop Findings [Crusan]
- 12) The Global Exploration Roadmap [Laurini]
- 13) International Space Station Status [Gatens]

**Reports:**

- 1) Aerospace Safety Advisory Panel Annual Report for 2017
- 2) NASA Knowledge Journal, Office of the Chief Knowledge Officer, Winter 2017

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<sup>1</sup> Available at: <https://www.nasa.gov/directorates/heo/nac-heoc>