National Aeronautics and Space Administration
Washington, DC

NASA ADVISORY COUNCIL

Human Exploration and Operations Committee

December 6-7, 2018

NASA Headquarters
Washington, DC

MEETING MINUTES

_____
Kenneth Bowersox, Chair

_____
Bette Siegel, Executive Secretary

Human Exploration and Operations Committee Meeting
NASA Headquarters
Glennan Conference Center, Room 1Q39
300 E Street SW
Washington, DC
December 6-7, 2018

MEETING MINUTES

TABLE OF CONTENTS

Minutes Prepared By:
David J. Frankel, consultant
P B Frankel, LLC

Human Exploration and Operations Committee
NASA Headquarters
Glennan Conference Center, Room 1Q39
300 E Street, SW
Washington, DC 20546
December 6-7, 2018

Thursday, December 6, 2018

Call to Order, Welcome, and Opening Remarks

Dr. Bette Siegel, Executive Secretary for the NASA Advisory Council (NAC) Human Exploration and Operations (HEO) Committee, called the session of the HEO Committee to order at 8:30 a.m. and welcomed everyone to NASA Headquarters. Dr. Siegel announced that it was a Federal Advisory Committee Act (FACA) meeting and, therefore, will be open to the public. Minutes will be taken and posted online, along with the written presentations. Dr. Siegel explained that there will be an opportunity for the public to make comments towards the end of that day's 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, Associate Administrator (AA), NASA Human Exploration and Operations Mission Directorate (HEOMD), who briefed the Committee on events relating to the HEOMD.

Mr. Gerstenmaier discussed the President's three space policy directives. He explained that Space Policy Directive (SPD)-1 "is really important." It calls on NASA to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." The policy further provides that "beginning with missions beyond low-Earth orbit (LEO), the U.S. will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations." The first paragraph, particularly the word "sustainable," is the most important part of the directive. Mr. Gerstenmaier noted that his staff would emphasize the second paragraph. He suggested that the Committee discuss the importance of sustainability to be sure it is understood and generate recommendations concerning it. SPD-2 calls for streamlining regulations on the commercial use of space and provides: "It is the policy of the executive branch to be prudent and responsible when spending taxpayer funds, and to recognize how government actions, including Federal regulations, affect private resources. It is therefore important that regulations adopted and enforced by the executive branch promote economic growth; minimize uncertainty for taxpayers, investors, and private industry; protect national security, public safety, and foreign policy interests; and encourage American leadership in space commerce." SPD-3 addresses national space traffic management and states: "For decades, the United States has effectively reaped the benefits of operating in space to enhance our national security, civil, and commercial sectors. Our society now depends on space technologies and space-based capabilities for communications, navigation, weather forecasting, and much more. Given the significance of space activities, the United States considers the continued unfettered access to and freedom to operate in space of vital interest to advance the security, economic prosperity, and scientific knowledge of the Nation."

Mr. Gerstenmaier described NASA's path to moving human presence into the solar system. NASA will:

- build an infrastructure that will make deep space accessible to all of humanity;
- develop incremental capabilities during human lunar expeditions that will inform future missions, deeper into the solar system; and
- expand our near-Earth economy to establish a sustainable presence in deep space, as we are already doing in LEO.

The strategic principles of human space exploration require fiscal realism, commercial partnerships, scientific exploration, technology pull and push, gradual buildup of capability, architecture openness and resilience, global collaboration and leadership, and continuity of human spaceflight. He noted that a budget increase beyond one percent is not expected.

Mr. Gerstenmaier discussed international interoperability standards. NASA, in collaboration with the International Space Station (ISS) partners, has developed a draft set of deep-space interoperability system standards in seven areas: avionics, communications, environmental control and life support systems (ECLSS), power, rendezvous, robotics, and thermal. The purpose for the standards is to enable industry and international entities to independently develop systems and elements for deep space that would be compatible aboard any spacecraft and to facilitate cooperative deep-space exploration endeavors. Anyone who builds to the standards should be able to use NASA facilities.

Mr. Gerstenmaier presented slides on commercial cargo transportation and commercial crew transportation. The SpaceX Dragon uncrewed demonstration flight is scheduled for the end of January 2019. Boeing's uncrewed demonstration flight will be later that year. He presented a slide on the deep-space exploration system, which includes the heavy-lift Space Launch System (SLS), the Orion crew vehicle, Exploration Ground Systems (EGS), and the cislunar Gateway. He described recent accomplishments in the deep-space exploration system. He reviewed a chart showing the planned trajectory for the unmanned Exploration Mission (EM)-1. EM-1 is designed to test hardware in a distant retrograde orbit (DRO), which is a very rigorous environment. Mr. Gerstenmaier reported that his team had suggested using an easier trajectory; however, he believes the DRO represents a better opportunity to test the hardware. The mission will travel 1.3 million miles, last for 25.5 days, re-enter the Earth's atmosphere at 24,500 mph (Mach 32), and deploy 13 CubeSats. He also discussed the planned trajectory for EM-2, which will demonstrate crewed flight and spacecraft systems performance beyond LEO. It will carry 4 astronauts on a lunar flyby, travel 1,090,320 kilometers (km), last 9 days, and reenter Earth's atmosphere at 24,500 mph.

Mr. Gerstenmaier discussed Gateway. It is not just a smaller version of the ISS in lunar orbit. It will provide a strategic presence in cislunar space that will drive activity with commercial and international partners, help explore the Moon and its resources, and leverage that experience toward human missions to Mars. It is the key to a reusable in-space architecture. Gateway needs to be human safe but not human rated, since there will always be an attached rescue vehicle. Mr. Gerstenmaier presented a chart showing the planned trajectory for EM-3, which will travel to a near-rectilinear halo orbit (NRH0) and deliver the first habitation element for Gateway. He presented a graphic showing the current configuration concept for Gateway's elements. Gateway will provide a 50 kilowatt (kW) Solar Electric Propulsion (SEP), carry 4 crew members on 30- to 90-day missions, provide 125 cubic meters (m^3) of pressurized volume, and weigh up to 75 metric tons with Orion docked. It will remain in orbit approximately 384,000 km from Earth and be accessible by NASA's SLS as well as international and commercial vehicles. It will serve as a communications relay for service and orbital robotic missions, and it will provide high-rate communications to and from Earth. The orbit will keep the crew in constant communication with Earth and out of the Moon's shadow. Gateway will support payloads internally, affixed

outside, free-flying nearby, or on the lunar surface. Experiments and investigations will continue operating autonomously on Gateway when crew is not present.

Mr. Gerstenmaier presented a graphic showing how the Gateway would be located in a gravity well between the Earth and the Moon. He explained that NASA is learning how to maneuver in deep space with minimal delta velocity (ΔV). He discussed the difference between low lunar orbits (LLOs), DROs, and halo orbits. LLOs are difficult to maintain and have an orbital period of two hours. DROs are stable and easy to reach from Earth but are far from the lunar surface. NRHOs are fuel efficient orbits revolving around Earth-Moon neutral-gravity points and have an orbital period of one to two weeks. They are easy to access from Earth, useful for radiation testing and experiments in preparation for missions to the lunar surface and Mars, provide a favorable vantage point for science observations, provide continuous view of Earth and a communications relay for the lunar far side, and provide a staging point for planetary sample return missions. Mr. Gerstenmaier presented a chart showing a notional buildup for Gateway from 2020 through 2026. He noted that many people have difficulty seeing the advantages of Gateway and suggested that that be a topic for consideration by the Committee.

Mr. Gerstenmaier discussed lunar transportation technology under development by the Science Mission Directorate (SMD), the Space Technology Mission Directorate (STMD), and HEOMD's Advanced Cislunar and Surface Capabilities (ACSC). ACSC, along with other Exploration Campaign activities, will re-establish U.S. preeminence to, around, and on the Moon. It will invest with industry providers, purchase lander services to test subsystems, and use innovative acquisition approaches to enable U.S. commercial capabilities to be leveraged toward human exploration of the lunar surface and partner with international partners. The first human-class descent element flight test is planned for 2024.

Mr. Gerstenmaier described habitation development partnerships under which five full-sized ground prototypes for Gateway habitats will be delivered for testing in 2019. NASA is leading and facilitating a sustainable architecture program that is open to and relies on international and commercial partners. He reviewed a slide showing the path to the lunar surface. Mr. Gerstenmaier described the three-stage lunar architecture, which has an ascent element, a descent element, and a transfer vehicle. He discussed long-term exploration and utilization of the Moon. NASA is developing a new approach to human exploration using an open framework in space that is open to multiple destinations and missions. It leverages commercial and international partnerships and allows human exploration to advance at a pace that is sustainable.

Mr. Gerstenmaier presented slides on Space Communications and Navigation (SCaN). NASA is considering using the existing Earth global positioning system (GPS) satellite constellation for navigation around the Moon. He discussed crew performance after landing. Every returning crewmember exhibits vestibular, cerebellar, and sensorimotor decrements. All crewmembers experience landing-related motion sickness. Some crewmembers are unable to touch their noses, and it is important, therefore, to make sure that instrumentation switches are properly located. Because of this problem, emergency egress during and after a water landing will present a significant risk to astronaut safety. NASA is working on mitigating this issue.

Mr. Gerstenmaier concluded his presentation by describing the Cold Atom Laboratory (CAL). It is a facility for quantum science on the ISS and allows scientists to produce ultra-low temperatures. Ultra-cold samples created at CAL can float unconfined for long periods, nearly fixed in space relative to the apparatus. CAL will be used to test quantum entanglement, also known as Einstein's "spooky action at a distance ", and other phenomena which take place at the quantum level.

Mr. Bowersox thanked Mr. Gerstenmaier for his presentation.

International Space Station Update

Mr. Bowersox introduced Mr. Sam Scimemi, ISS Director, who provided an update on the ISS.

Mr. Scimemi reviewed the flight plan for Increment 57 and presented a slide showing the crew members on Increments 57 and 58. Due to the recent Soyuz launch, there are once again six crewmembers on the ISS. Soyuz 55S is returning to Earth on December 20, 2018, and Soyuz 56S will be returning in June 2019. The next Soyuz launch is scheduled for March 1, 2019, and will bring the crew back up to six members again. He reviewed a chart showing the schedule for Increments 57 and 58.

Mr. Scimemi discussed the fiscal year (FY)18-19 Agency Priority Goal for the ISS, which states: "Use the International Space Station (ISS) as a testbed to demonstrate the critical systems necessary for long-duration missions. Between October 1, 2017, and September 30, 2019, NASA will initiate at least eight in-space demonstrations of technology critical to enable human exploration in deep space." Mr. Scimemi explained that the goal focuses on Exploration-enabling demonstrations to be conducted on the ISS. He reviewed a chart showing the demonstrations currently planned for FY19. One demonstration will be the ISS Hybrid Electronic Radiation Assessor (HERA), which uses an existing on-orbit primary radiation detection system developed for Orion and EM-1 that has been modified for use on the ISS. The investigation provides an opportunity to evaluate the hardware in a space radiation environment before the EM-1 flight.

Mr. Scimemi reviewed a chart on the Human Research Program (HRP) Path to Risk Reduction. He described the Advanced Twin Lifting and Aerobic System (ATLAS) exercise device that will be tested on the ISS in 2020 and is intended for use on Orion. The European Space Agency (ESA) is developing a similar device named "Tarzan;" there will be a "flyoff" to determine which device will be flown on Orion. Dr. Pat Condon asked whether any experiments were planned to address eye-hand coordination degradation. Mr. Scimemi responded that a lot is being done in the zero-gravity environment but not in the one-gravity environment. Dr. David Longnecker asked whether commercial industry had participated in developing the exercise equipment. Mr. Scimemi responded that he was not familiar with how the equipment is being developed.

Mr. Scimemi reviewed a chart showing the Increment 57 crew time utilization. He noted that utilization averaged close to 35 hours per week despite a reduced crew size of 3 people. He hopes to return to a regular cadence after March. Mr. Scimemi discussed a chart showing ISS research statistics. To date, 106 nations have had some role in research on the ISS. He presented charts listing research investigations on increments 57 and 58. He described the Global Ecosystem Dynamics Investigation (GEDI). From its location on the exterior of the ISS orbiting laboratory, GEDI will be the first space-borne laser instrument to measure the structure of Earth's tropical and temperate forests in high resolution and three dimensions. Those measurements will help understand how much carbon is stored in the world's forests, the potential for ecosystems to absorb rising concentrations of carbon dioxide in Earth's atmosphere, and the impact of forest changes on biodiversity.

Reliability Statistics, Planned Versus Actual for ISS Components

Mr. Scimemi briefed the Committee on ISS maintenance trends. He described the analytical process and reviewed charts on corrective maintenance trends for external equipment, internal equipment, pressurized upmass, unpressurized upmass, command and data handling systems, and the ECLSS. Overall, the ISS continues to perform better than predicted. Bayesian analysis has significantly closed the gap between actual and predicted maintenance demands. NASA has implemented a semi-annual Bayesian update process to improve the accuracy of maintenance projections and is continuing to refine the correlation of predicted corrective maintenance with actual on-orbit experience. As operational experience is established, actual and projected maintenance demand should converge. Mr. Bowersox commented that the data is very important for going to Mars and indicates that ground testing is good for much of the hardware. He added that NASA could never afford going to Mars if there is too much conservatism. Ms. Robin Gatens, Deputy ISS Director, stated that the current prediction for spare parts for going to Mars is prohibitive. Mr. Tommy Holloway cautioned against translating the data to Mars and explained that "if one item messes up you've had a terrible day." Mr. Scimemi responded that NASA is working on dissimilar redundancy.

Mr. Bowersox thanked Mr. Scimemi for his presentation.

Commercial Crew

Mr. Bowersox introduced Mr. Phil McAlister, who briefed the Committee on the status of the Commercial Crew Program (CCP). Mr. McAlister explained that he would not be able to discuss proprietary issues because the meeting was open to the public.

Mr. McAlister summarized recent program progress. Mission planning and preparations for eight CCP missions are underway. Boeing has three vehicles and SpaceX has eight vehicles in development. The providers are performing critical test and verification events and continue to make progress in the burn down of key certification products. Mr. McAlister noted that NASA has not flown a manned mission since 2011, and he expects there will be "challenges and bumps." The test flights will provide important information as progress is made towards certification. In response to a question from Mr. Lon Levin, Mr. McAlister explained that NASA's requirements are for two launches per year, which will be alternated between SpaceX and Boeing. He added that the providers may put extra people on the flights if there is excess capacity. The providers can launch additional flights to the ISS or elsewhere in LEO. NASA's requirement is for four people per flight, twice a year. In response to a question from Mr. Michael Lopez-Alegria, Mr. McAlister explained that each test flight has its own objectives, such as ascent, docking, remaining on orbit, and descent. Most of the systems will be exercised on each test flight. Mr. McAlister presented a slide showing the milestones under each commercial contract and noted that the difficult milestones are yet to be completed. He expressed hope that all remaining milestones would be completed by the end of 2019. The providers are paid for each milestone when it is completed. In response to a question from Dr. Condon, Mr. McAlister explained that final certification comes after the test flights.

Mr. McAlister reviewed a chart on the CCP's top programmatic risks. The highest risk is the potential inability to meet the contractually required probability for a 1 in 270 chance for loss of crew (LOC). Mr. Wayne Hale explained that the biggest contributor to the LOC probability is the ability to remain on station for 180 days without damage from micrometeoroids or orbital debris (MMOD). Dr. Patricia Sanders, Chair of the Aerospace Safety Advisory Panel (ASAP) advised that the contractually required LOC probability had served a useful purpose and forced design solutions; however, there is quite a bit uncertainty in the numbers and it might be

reasonable to modify the criteria. A Mr. McAlister stated that the LOC probability is based on a probabilistic safety assessment model and could be modified if the provider requests a variance. Mr. Lopez-Alegria asked when the LOC requirement would have to be met. Mr. McAlister responded that it had to be met sometime before final flight certification and that he would research the question and provide the Committee with the exact contractual requirement.

Mr. McAlister discussed the status of Boeing's test flight mission. He reviewed Boeing's recent accomplishments and presented slides on Boeing's Crewed Flight Test (CFT) and Orbital Flight Test (OFT) spacecraft. He described Boeing's work on Cape Canaveral Space Launch Complex 41 and the Atlas V CFT and OFT launch vehicles. He described the status of Boeing's flight operations reviews, its operations training and simulations, and its completed Emergency Egress System validation test. Mr. McAlister then discussed the status of SpaceX's Demo-1, Demo-2, and Crew-1 missions. He described SpaceX's recent accomplishments and presented slides on the Demo-1, Demo-2 Dragon, and Crew-1 Dragon vehicles. He described the status of work on SpaceX's Falcon 9 launch vehicle and Pad 39A. He discussed the status of SpaceX operations.

Seven flights are needed for certification, and there are six post-certification missions (PCM) for each company after certification. Mr. McAlister stated that he is very proud of the commercial partners and what they accomplished during the past quarter. Mr. Bowersox commented that the ASAP has been taking the lead on conducting external safety reviews. Mr. McAlister stated that the commercial providers conduct their own safety reviews and that there are additional external reviews by NASA's technical authorities (embedded in the program), the Standing Review Board, the General Accounting Office (GAO), the Inspector General (IG), and the Congress. In response to a question from Mr. James Voss, Mr. McAlister explained that the final approval process will be like a typical NASA flight. There will be a Flight Readiness Review (FRR) chaired by the HEO AA. NASA can pull its astronauts from the flight if NASA is not comfortable. PCM missions will be certified by the Federal Aviation Administration (FAA). Mr. Levin observed that NASA's astronauts would be trained by commercial providers and asked Mr. McAlister to discuss the oversight and insight for that training. Mr. McAlister explained that oversight refers to governmental authority to tell a contractor what to do and insight is a passive factor for gaining an understanding on how the systems would operate. NASA does not want to tell the providers what to do for the pad, crew capsule, or launch vehicle as long as the contractual requirements are met. NASA must verify and validate that the provider has met the contractual requirements. Mr. Hale commented that the CCP has always been considered an experiment, and it will continue to be an experiment until the vehicles are certified. Mr. Mark McDaniel asked what interest NASA had in taking a Boeing astronaut on the Boeing test flight. Mr. McAlister responded that it is up to Boeing. Mr. Bowersox commented that international partners would be present at the FRR. Mr. McAlister added that NASA personnel would be present on the console at launch and would need to approve flights launching NASA astronauts. In response to a question from Mr. Levin, Mr. McAlister stated that NASA would have to work out with the provider how payments would be handled if NASA pulled its astronauts from a flight. In response to a question from Ms. Nancy Ann Budden, Mr. McAlister explained that the flight director would be a company employee. There will be a transfer of authority when the vehicle reached the ISS "keep out" zone. Dr. Sanders remarked that the same is true for commercial resupply flights.

Mr. McAlister described "no exchange of funds" Space Act Agreements (SAAs) with Blue Origin and Sierra Nevada. The long-term interest is that those companies will become crew transportation providers. Both companies have a goal to fly people to space. Under the SAAs, NASA provides technical advice to them and pays for its participation, and the companies pay for their own development costs.

Mr. Bowersox thanked Mr. McAlister for his presentation.

Exploration Systems

Mr. Bowersox introduced Mr. Tom Whitmeyer, Assistant Deputy AA for Exploration Systems Development (ESD).

Mr. Whitmeyer presented a chart showing the completed and remaining milestones for EM-1, which will fly by the Moon approximately 63 miles from its surface. He described the final parachute test for the Orion Spacecraft. He presented a chart on the EM-1 Launch Abort System (LAS). He described the work remaining on the EM-1 Crew Module (CM). The Crew Module Adapter (CMA) is ready to mate with the European Service Module (ESM). He presented slides showing the ESM arrival at NASA's Kennedy Space Center (KSC) onboard an Antonov An-124 jumbo jet. Mr. Whitmire reviewed the steps for mating the CMA to the ESM. He presented a video showing the testing on the integrated stack that will be conducted at NASA's Glenn Research Center (GRC) remote test installation, Plum Brook Station, which has the world's largest thermal vacuum chamber. In response to concerns expressed by Dr. Condon about thermal test uniformity, Mr. Whitmeyer explained that the testing would be differential. Dr. Condon stated that it does not look like they can heat one side and cool the other at the same time. Mr. Whitmeyer responded that there is another facility where that testing would be conducted. He discussed flight software development and testing at the Lockheed Martin Integrated Test Lab (ITL).

Mr. Whitmeyer described progress on the EM-1 Interim Cryogenic Propulsion Stage (ICPS), the Orion Stage Adapter (OSA), and the Launch Vehicle Stage Adapter (LVSA). He discussed the EM-1 Boosters. The segments are finalized, in storage, and ready for shipment in February 2019. The EM-1 RS-25 engines were delivered in place in October 2017. Five of ten tests on the engines are complete. He described software qualification testing at the Software Integration Test Facility (SITF) located at NASA's Marshall Space Flight Center (MSFC).

Mr. Whitmeyer discussed progress on the EM-2 SLS and described EGS progress at KSC, including the Umbilical Launch Equipment Testing Facility (LETF). He reviewed work for EM-1 and EM-2 that has been completed at the Vertical Assembly Building (VAB) and at KSC Pad 39B. He noted that the Multi-Payload Processing Facility (MPPF) is ready to support vehicle processing. He presented a chart showing how the rocket stack will be assembled and noted that the SLS tanks will be integrated horizontally because they are too long to integrate vertically. Mr. Whitmeyer described the Spaceport Command and Control System (SCCS) and the status of Ground Flight Application Software (GFAS).

At Mr. Bowersox's request, Mr. Whitmeyer described the difference between the first and second SLS build. Mr. Bowersox recalled Mr. Gerstenmaier's remarks that the challenge would be to get to one SLS flight per year. Mr. Whitmeyer responded that it would depend on having enough funding to fly that often. Mr. Hale commented that the critical item for EM-3 is the Exploration Upper Stage (EUS). Mr. Whitmeyer responded that EM-3 would be the first flight for the EUS. In response to a question from Ms. Budden, Mr. Whitmeyer explained that acoustic testing on the SLS would be performed at KSC with speakers used at rock concerts.

Mr. Whitmeyer concluded his presentation with an inspirational video showing an Orion mission launching from KSC and orbiting the Moon.

Mr. Bowersox thanked Mr. Whitmeyer for his presentation.

Public Comments

Mr. Bowersox invited comments from the public. There were none.

Discussion and Recommendations

After noting that Mr. Bob Sieck was participating via telecom, Mr. Bowersox asked the Committee members to review the Committee's observations from its last meeting. Mr. Levin stated that the CCP is an experiment that seems to be working. Ms. Budden concurred. Mr. Lopez-Alegria commented that complaints that "there is a need for less bureaucracy at NASA" would not make a difference and is like saying "I want a pony." He added that NASA will never meet schedule and cost for big programs. He also expressed disappointment that there had not been any presentations at the meeting on the ISS transition and observed that NASA would not plan anything for the transition until it learns more about its budget. Mr. Bowersox noted that industry studies on the transition had been requested and are due later in the month. Ms. Budden commented that NASA has become more risk adverse, and she suggested that it is time to advance risk margins. Mr. Holloway complimented the Russian Space Agency's ability to turn around the recent Soyuz failure and be able to return to fly in two months. Dr. Longnecker reported that NASA's root cause analysis methodology has been applied to surgery. Mr. Holloway recalled that NASA "didn't know anything when we started in 1959. The Gemini hardware was 'absolutely lousy.' The hardware on Apollo was outstanding and the hardware failure was caused by human failure." He suggested that NASA "pay no attention to risks that are stirred up by do-gooders." He added that "NASA can't worry about satisfying every bureaucrat in the system." Ms. Ruth Gardner recommended that there should be more trust in Mr. Gerstenmaier. Mr. Bowersox cautioned against treating every risk the same way. Care should be exercised not to over-constrain program managers. Mr. Lopez-Alegria stated that the two Space Shuttle accidents could have been avoided "by listening to the people in the trenches." Dr. Sanders advised that safety and mission success risks must be prioritized above risks to cost and schedule. When a risk is accepted, the potential consequences must be accepted. Mr. Sieck commented that a NASA-trained astronaut is a national asset and that NASA would be held accountable if something bad happened to a NASA astronaut on a CCP mission.

Mr. Hale expressed concern over not hearing enough about software and expressed the belief that "NASA may be a little too 'Pollyannaish' about that critical topic." Mr. Bowersox noted that every program manager who has briefed him on the topic has said "it is important to worry about software all the time." Mr. Hale asserted that the loss of Challenger and Columbia were more about management failures than hardware failures. Mr. Voss suggested that funds should be spent on a lunar surface suit. He added that there has been a "push back on Gateway," and he suggested that NASA should express the rationale for Gateway in a better way. He also noted that Mr. Gerstenmaier had requested help in that regard. Dr. Leroy Chiao suggested the need for "the simple elevator speech." He added that something should be said about the anti-bureaucracy sentiment and noted that program managers are already over-constrained. Mr. Bowersox commented that the whole country has changed and become more risk averse. Mr. Holloway observed that "NASA got to the moon by taking a lot of risk" and now needs to "manage risk rather than being managed by risk." He applauded the CCP for reducing costs and avoiding the NASA bureaucracy. He cautioned, however, that "Boeing's bureaucracy is not any better than NASA's." Mr. Holloway listed five reasons for Apollo's success:

1. Commitment at all levels.
2. Unlimited budget.
3. World class leaders.

4. Little or no bureaucracy.
5. A lot of new hires, who were turned loose.

Mr. Bowersox asked the Committee members for suggestions on reasons to support Gateway. After discussion, the Committee developed the following reasons:

- The team with the most insight into the problem over the last 12 years is recommending the cislunar orbiting platform (Gateway) for development of cislunar capability.
- For the past 12 years, we've been changing plans and goals for future exploration after Shuttle and ISS – if we keep changing plans we'll never get anywhere. It is time to pick an approach and just go do it.
- We've already been to the lunar surface – why not do something more challenging, which will develop capability to go beyond the Moon?
- Gateway is for Mars exploration like Gemini was for Apollo – a natural stepping stone for deep-space operations.
- Gateway is a testbed for propulsion technology (solar electric) and other engineering testing that will enable deep-space exploration but can't be performed on ISS.
- Mars is what makes Gateway interesting.
- Gateway will be in an orbit that minimizes propellant used to deliver crew and cargo to cislunar space.
- Gateway can be used to enable return from Mars to cislunar space.
- Gateway will enable development of rendezvous techniques and other operations for deep space.
- Gateway is a place to try out things far from Earth and far from the Moon.
- The cislunar orbital platform (Gateway) is a multi-mission infrastructure element that will enable the development of many new capabilities.
- Switching to a direct lunar surface architecture at this point sounds simple, but there is a lot to work out. Switching is not likely to save time or money.
- Switching to a different option at this point will result in a two-year delay before anything new gets going.
- Apollo was cancelled because of affordability; at least two attempts to go back to the Moon have been terminated due to affordability.
- Apollo left no infrastructure on the Moon, so there is no need to return.
- Whatever comes next, the budget needs to be reasonable, or we'll find it terminated.
- The cislunar orbiting platform (Gateway) is intended to get us back to the Moon in a sustainable program, with budgets similar to what we are spending today.
- The cislunar orbiting platform (Gateway) is a great place to gain experience with many of the operations we will need for missions to Mars and beyond (complex rendezvous, SEP, refueling of landers or ascent vehicles, caching supplies).
- The cislunar orbiting platform (Gateway) isn't just about going to the lunar surface or going to Mars; it's about both and about going beyond.
- Gateway will provide an infrastructure element where visiting vehicles can be serviced and refueled, and where SEP can be tested.
- Using the cislunar orbiting platform (Gateway) as a base camp/foothold in cislunar space makes it more likely we'll see humans back on the lunar surface. With something so close we'll be drawn to the surface again.
- If you have trouble getting to the top of the mountain, build something that will help you on your next attempt to get to the top – the base camp. The cislunar orbiting platform (Gateway) is like a base camp that helps you develop skills and store supplies to get to the top of the mountain.
- The base camp approach will be useful at Mars and other points humans will visit in the solar system – Gateway is an opportunity to develop the skills needed to operate using a base camp.

- Gateway will inspire missions to the lunar surface, Mars, and beyond.
- The cislunar orbiting platform (Gateway) could enable refueling and servicing of reusable vehicles to transport crew, supplies, and samples to/from various points on the surface.
- The cislunar orbiting platform (Gateway) can be a safe haven for crews in the event of some vehicle malfunctions.
- The cislunar orbiting platform (Gateway) is a good place to cache supplies, parts, and fuel for cislunar operations.
- The cislunar orbiting platform (Gateway) is in a NRHO orbit that can be reached with less fuel than is required to go to the lunar surface.
- The cislunar orbiting platform (Gateway) can transition to orbits other than NRHO for a small propellant cost.
- The cislunar orbiting platform (Gateway) is not constrained to fly in a NRHO – if desired Gateway could travel much farther away from the Moon for experience in deep-space operations.
- The cislunar orbiting platform (Gateway) enables international and commercial partners to contribute with less investment than lunar surface operations – and sooner.
- A persistent presence is more likely to enable partnerships.
- Going directly to lunar surface operations without Gateway may be too challenging for commercial operators.
- International and commercial partnerships can currently support the Gateway infrastructure.
- Gateway is not ISS around the Moon; Gateway is intended to be procured a different way with much less cost – more like commercial cargo than either commercial crew or Orion.
- Gateway provides the flexible, reusable, and sustainable infrastructure to support space exploration. It enables learning about the deep-space environment, exploring and exploiting the surface of the Moon, developing technologies and operations for deep-space travel, and providing a cost effective jumping off point for going to Mars.
- A project with more reusable elements will be more sustainable. Gateway enables reusability.
- The science community has expressed a great interest in the research that could be conducted on Gateway.
- A base in the Antarctic has been very useful in biological sciences. An isolated remote site like Gateway opens up lots of research opportunities.
- NRHO has some features that make it interesting for national defense purposes.
- Gateway makes it possible to use of all the capabilities available in the U.S. and international partner countries to further human exploration – Orion, SLS, commercial launchers, international launchers, international transport vehicles – and future elements to be provided by international partners.
- Gateway allows different elements to be built and operated by different partners, providing multiple options that minimize chances that any one partner will be in the critical path for conducting interesting missions in cislunar space.
- The Gateway is a natural progression from ISS; ISS is an important precursor for exploration development on Gateway.

Mr. Bowersox noted that the Committee might be interested in developing a Finding on risk and the relative importance that risk has for safety, mission assurance, cost, and schedule.

Dr. Siegel adjourned the meeting at 4:05 p.m.

Friday December 7, 2018

Call to Order

Dr. Siegel called the meeting to order at 8:00 a.m. and made several announcements. The meeting is a FACA meeting and, therefore, will be open to the public. Minutes will be taken and posted online, along with the presentations. All committee members have submitted financial disclosure forms and will recuse themselves if there is a conflict of interest. She then introduced Mr. Bowersox.

Gateway

Mr. Bowersox welcomed everyone to the second day of the Committee's meeting. He introduced Mr. Jason Crusan, Director, HEOMD Advanced Exploration Systems (AES), who briefed the Committee on Gateway.

Mr. Crusan presented a graphic showing how cislunar space will be used as a deep-space harbor for Exploration missions. He explained that cislunar space is the next "high ground" beyond LEO. It is only 3 to 5 days away from Earth and is an ideal mission aggregation location accessible by NASA, commercial, and international launch systems. It provides a true deep-space radiation environment like the transit between Earth and Mars. It has a benign MMOD environment, and the station-keeping requirements are minimal. There are infrequent eclipse periods that are avoidable, and the thermal environment is compatible with cryogenic oxygen and methane. He explained that the NRHO is an elliptical orbit that can have a either a north pole or a south pole bias. The NRHO takes less fuel to reach than LLOs and is easier to get to than Lagrange points. In response to a question from Ms. Budden, Mr. Crusan confirmed that less fuel is needed to maintain a spacecraft in NRHO.

Mr. Crusan discussed human lunar lander development. Under the requested funding for ACSC, along with other Exploration campaign activities, NASA intends to re-establish U.S. preeminence to, around, and on the Moon. NASA will invest with industry providers, purchase lander services to test sub-systems, use innovative acquisition approaches to leverage U.S. commercial capabilities toward a Human Landing System, and partner with international partners. He presented a chart showing three phases of lunar transportation technology under development by SMD, STMD, and HEOMD. The first demonstration is planned for 2024 with at least one human-class descent element flight test. He described a three-stage lunar architecture. An ascent element using 2,850 meters per second (m/s) ΔV will be based at Gateway. It will carry a crew of four and will be reusable and refuelable. A descent element using 2000 m/s ΔV will serve as a cargo lander. A transfer vehicle using 850 m/s ΔV will transfer ascent and descent elements from Gateway's orbit to an LLO for landing. Mr. Crusan noted that a single-stage human lander would not fit on any current launch vehicle, including the SLS. A two-stage ascent and descent option would not fit on commercial launch vehicles. The three-stage option fits on commercial launch vehicles and allows increased partnering opportunities. He presented a chart comparing the ΔV for Gateway to the ΔV for a direct flight to the Moon. In response to a question from Mr. Bowersox, Mr. Crusan explained that there would be no need to bring Orion down to low lunar orbit.

Mr. Crusan presented a slide showing the Gateway objectives. The primary objective is to establish Gateway to enable a sustained presence around and on the Moon and to develop and deploy critical infrastructure required for operations on the lunar surface and at other deep-space destinations. Other objectives are to support crewed missions, science requirements, proving ground and technology demonstrations, and partnerships. Gateway will provide NASA with an opportunity to learn how to fly heavy objects in space. In response to a question from Ms. Budden, Mr. Crusan explained that crew would not be on board during the estimated 150 days that Gateway takes to change orbits. He added that orbit changes will be accomplished with SAP and small

orbit tweaks may be done with chemical. Transits to Mars would be based on hybrid propulsion that may include nucleal thermal propulsion. In response to a question from Dr. Condon, Mr. Crusan explained that commercial partners could provide services, and international partners would barter. In response questions from Dr. Sanders and Dr. Condon, Mr. Crusan concurred that commercial partners could provide their own landers and that a commercial partner could engage in bartering like an international partner. He added that under the Gateway governance model, industry partners bringing contributions could expect commensurate benefits. Mr. Holloway commented that international partners would not do anything unless NASA gives up some rights. Most likely they will want to put crew on board and send them to the lunar surface. Mr. Crusan responded that having a four-person crew would optimize the opportunity to make trades. In response to a question from Mr. Holloway, Mr. Crusan explained that Orion could augment Gateway's systems. Orion is subject to a 21-day consumable limit; Gateway's volume is likely to be close to 125 cubic meters, and the ISS has ten times that volume. For that reason, you would not want to conduct ISS-like research on Gateway. In response to another question from Mr. Holloway, Mr. Crusan explained that longer missions on the lunar surface would require pressurized elements on the Moon.

Mr. Crusan discussed the Gateway orbit. He explained that cislunar space offers innumerable orbits for consideration, each with merit for a variety of operations. He described the different types of orbits. An LLO is circular or elliptical and is close to the surface. It is excellent for remote sensing; however, it is difficult to maintain in the Moon's gravity well. Its orbit period can be close to two hours. A DRO is a very large, circular, stable orbit. It is easy to reach from Earth but is far from the lunar surface. Its orbit period is two weeks. A halo orbit is fuel-efficient and revolves around Earth-Moon neutral-gravity points. Its orbit period is one to two weeks. A NRHO is 1,500 km at its closest to the lunar surface and 70,000 km at its farthest. It provides easy access from Earth with many current launch vehicles. Its deep-space environment is useful for radiation testing and experiments in preparation for missions to the lunar surface and Mars. NRHO provides a favorable vantage point for Earth, Sun, and deep-space observations. It provides a continuous view of Earth and a communication relay for the lunar far side. It provides a staging point for planetary sample return missions. Mr. Crusan presented a video showing the transition from a NRHO to a DRO. In response to a question from Mr. Lopez-Alegria, he explained that it could take up to eight days in the worse case scenario for the Gateway crew to return to Earth if there were an emergency. Mr. Voss requested statistics to show the advantages of NRHOs compared to LLOs for orbit maintenance and systems maintenance. Mr. Crusan agreed to provide that information in the future.

Mr. Crusan discussed NASA's plans to procure logistics sources for Gateway. A Sources Sought Notice has been issued asking U.S. companies to provide NASA with information regarding options to transport cargo, equipment, and other goods to and from Gateway near the Moon. The first two logistics modules will likely launch on commercial rockets, but after Gateway assembly, NASA's SLS will be available as well. Mr. Crusan presented a slide showing graphics for NextSTEP-2 deep-space habitation prototypes under development by Lockheed Martin, Northrop Grumman, Bigelow Aerospace, Boeing, Sierra Nevada, and NanoRacks. Dr. Sanders commented that those habitats could be prototypes for Mars transit habitats. Mr. Crusan reviewed the Gateway milestones that have been completed and observed that everything is on schedule. Mr. Voss commented that he has heard that Gateway is not the best way to do science or go to Mars. Mr. Crusan responded that while mathematics would not say Gateway is more efficient, other considerations are reusability, refuelability, and overall sustainability. Mr. Bowersox commented that Gateway would be advantageous and make sense for going beyond the Moon. Ms. Budden advised that NASA should "give up" on the Gateway option if its justification has to rely on talking about the orbit. Mr. Bowersox commented that directmay be the way to go if

NASA was only interested in just getting back to the lunar surface. Mr. Hale remarked that "Gateway is not the fastest, not the cheapest, but it's the best."

Mr. Bowersox thanked Mr. Crusan for his presentation.

Power Propulsion Element Update

Mr. Bowersox introduced Dr. Michele Gates, Program Director, Power and Propulsion Element (PPE). Dr. Gates presented a graphic showing the PPE with a launch in 2022 and a graphic showing the PPE with its very large solar arrays. She described the approach to PPE development. The PPE will be developed through a public-private partnership that leverages U.S. industry capabilities and SEP technology development. In addition to propulsion, PPE will provide power and communications for future Gateway elements. She gave the latest public timeline for the PPE procurement. Proposals have been received from industry in response to a Broad Agency Announcement (BAA) solicitation and are under evaluation. The selected partner(s) will own the PPE during its development and for up to one year during its space flight demonstration. NASA will have a contractual option to acquire PPE after the demonstration is completed. More than one provider may be selected. The partnership would conclude 24 months after successful space flight demonstration if all options are executed. In response to a question from Mr. Lopez-Alegria, Dr. Gates explained that the NASA Associate Administrator for Procurement had granted a deviation from the Federal Acquisition Regulations to allow the Agency to pursue a BAA in procurement strategy. Mr. Hale commented that it was "another in a series where NASA is not going to be totally in control" and would be interesting to follow. Dr. Sanders noted that PPE is also useful for testing the technology for going to Mars.

Dr. Gates presented a chart listing the following PPE NASA-unique space flight demonstration objectives:

- Demonstrate high-power, 50kW-class solar array and electric propulsion technology in relevant space environments.
- Demonstrate continuous long-term electric propulsion operation sufficient to predict the xenon throughput capability and lifetime of high-power systems.
- Demonstrate the deployment and successful long-term, deep-space operation of high-power solar array systems with applicability to future higher power missions.
- Characterize in-space operation of a next-generation electric propulsion string.
- Demonstrate integrated SEP end-to-end system performance in relevant space environments.
- Observe and characterize performance of integral high-power SEP system including thrusters, arrays, bus, and payloads as they operate as an integrated system and as they respond to the natural and induced in-space environments.
- Demonstrate extended autonomous high-power SEP operations in deep space.
- Demonstrate a high-data throughput uplink and downlink communication system.
- Demonstrate PPE insertion into a crew-accessible NRHO.
- Obtain design, development, and flight demonstration data to determine acceptability of the PPE for Gateway.

Dr. Gates noted that the Gateway program will soon transition from formulation to center program management. PPE partner selections will be made in March 2019. She presented a video showing Gateway in a NRHO. She presented another video showing the propulsion maneuvers needed to transfer from a NRHO to a LLO. Dr. Gates concluded her presentation with a chart showing PPE milestones that have been completed over the last quarter. Mr. Hale commented that "the problem on selling the program is that there are so many

options and permutations." In response to a question from Mr. Lopez-Alegria about how the stack attitude is controlled, Dr. Gates explained that the PPE would use chemical propulsion, control moment gyros, in addition to SEP. Ms. Budden complimented Dr. Gates for "cracking the code on using laymen's terms." Mr. Voss observed that PPE must succeed if Gateway is to succeed and that it is what NASA should be doing: implementing a high-risk program using a special procurement strategy. In response to a question from Mr. Bowersox, Dr. Gates explained that the program had been authorized funds for the previous year under a Continuing Resolution (CR) and that the program would continue only if it received funds under an extended CR.

Mr. Bowersox thanked Dr. Gates for her presentation.

Discussion and Recommendations

Mr. Bowersox asked the Committee members to consider potential Findings and Recommendations either from the NAC to the Administrator or from the Committee to the AA. Proposed Findings were presented to address management over-constraining program managers and NASA's heightened aversion to risk. Mr. Bowersox commented that it is "very hard to work innovative and risky programs through the system." Mr. Holloway stated it is not just the program managers, "it is the whole system that is the problem." Dr. Sanders observed that "all of NASA is constrained." Mr. Hale asserted that management needs to be constrained because nobody is perfect, and everybody makes mistakes. He added that Mr. Gerstenmaier's memorandum on risk could be the basis for an excellent Recommendation. Mr. McDaniel commented that Congress does not give NASA enough funding to lead the world in space exploration. Dr. Chiao stated, "there needs to be a culture change if they want the U.S. to continue to lead." Mr. Holloway stated, "what NASA is doing today is not innovative; it is repetitive." He added, "I had zero oversight in starting the Shuttle– Mir program." After further discussion, it was determined that additional briefings on the subject would be helpful, and the proposed Finding was tabled until the next Committee meeting. Dr. Condon advised that the issue needs to get the Administrator's attention, or nothing would happen. Dr. Sanders advised that there needs to be a way to get decisions made faster.

Mr. Hale suggested a Recommendation that there should be a reasonable name for SLS and Gateway. Mr. Bowersox agreed that naming Gateway would be a great recommendation and would help in communicating support for it. He said it could become a Committee Observation.

In closing discussion, Mr. Holloway stated, "If we are going to the Moon and making dozens of flights, then Gateway is the way to go; if you are going to Mars, it is not the right way to go. The politically correct decision is to build Gateway." Dr. Condon suggested boiling it all down to three main points. Ms. Budden suggested developing a "Fact Sheet" with 10 to 12 points.

Mr. Bowersox polled the Committee members on two questions: whether Gateway is the right way to proceed in order to implement SPD-1, and whether they prefer the Gateway approach to the Moon over the direct approach. The Committee members unanimously answered both questions affirmatively. Mr. Holloway noted that he voted affirmatively because it would sustain human space flight, although "NASA has forgone the possibility to go to Mars in his grandchildren's lifetime."

Mr. Bowersox reviewed the Committee's observations and concerns as well as proposed findings from its last meeting. Observations, Concerns as well as proposed Findings and Recommendations presented at the NAC meeting are shown below.

HEO Committee Observations

NASA has set forth a clear set of principles to guide its ISS transition plan for 2024 and beyond, and submitted a report on ISStransition to congress. The committee looks forward to reviewing the responses from industry to NASA's most recent NASA Research Announcement (NRA) on ISS transition, which are expected in December of 2018.

The Committee is encouraged to see the level of support from the president and congress for NASA's sustainable approach to human exploration beyond low earth orbit as evidenced by the president's space policy directives, the most recent NASA authorization act, as well as the 2018 and 2019 NASA budgets. It will be exciting for the committee to monitor and review plans for returning humans to cislunarspace and to the surface of the moon as they are developed over the next year. **At this meeting the committee saw some preliminary plans for lunar landers. More information is expected after the president's budget is submitted to congress.**

The committee members support NASA's plans for a lunar orbiting platform that will enable international and commercial partnerships, reusability of hardware to transport crews to and from the lunar surface, reduce risk for lunar exploration crews by providing a safe haven, improve communications with spacecraft on the lunar surface, and provide valuable opportunities for scientific investigations, while expanding the knowledge base in the area of deep space maneuvering and solar electric propulsion required for travel to Mars.
The 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. Where appropriate, other programs such as SLS and Orion should be allowed to take advantage of aspects of the commercial cargo program that enabled success at a lower cost. A similar procurement approach to that used for ISS cargo is planned for future programs such as PPE, the gateway habitation module, and some components of the lunar lander. It would be helpful to fully document and formalize the procurement and management approach that worked well for ISS cargo.

Complexity of commercial crew and gateway will result in integration challenges that should be anticipated to minimize problems. Approaches proven on ISS and clearly expressed standards will help to make the integration problem manageable.

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.

NASA has been working with their Russian partners to maximize the on orbit stay time for Soyuz vehicles which will ensure US crew presence at ISS through January of 2020. If operational availability of commercial crew vehicles for station crew rotation is delayed beyond January, 2020, US crew presence aboard ISS could be lost. The ISS and Commercial Crew programs are continuing to look for ways to keep US crew members aboard ISS, if the first commercial crew flights are delayed.

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 Orio. **If a reorganization is determnined to be the best course for NASA, SLS and Orion are at the point where they should remain part of the HEO organization**.

Proposed NAC Finding on the Gateway
After consideration of switching to a program that goes more directly to the lunar surface, the consensus of the HEO committee members is that NASA should continue moving forward with its sustainable approach to explore cislunarspace, including the lunar surface using the Gateway.

The NAC supports NASA's plans for a lunar orbiting platform that will enable international and commercial partnerships, reusability of hardware to transport crews to and from the lunar surface, reduce risk for lunar exploration crews by providing a safe haven, improve communications with spacecraft on the lunar surface, and provide valuable opportunities for scientific investigations, while expanding the knowledge base in the area of deep space maneuvering and solar electric propulsion required for travel to Mars.

The proposed finding was submitted by the committee and modified by the NAC as follows:

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

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

The committee proposed the following recommendation which was tabled for further discussion at a future session:

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

Major Reasons for the Recommendation: The NAC applauds NASA's work, consistent with the National Space Policy Directives in bringing back to earth new knowledge and opportunities through innovative and inspirational space programs and technical advances, which were based on a culture of discovery, risk acceptance and learning. NASA's rich history of managing large projects includes huge mission successes like

the Apollo program, Viking, Voyager, and the Hubble Space Telescope. The managers of these successful programs were given enough flexibility and resources to accomplish tasks that had never been done before. The council observes that the large programs of today are facing a change in the external and internal environment, which is creating a change in program and project management. The culture being created is focused on compliance and failure prevention at the expense of innovation and inspiration. Programs and projects are learning to pass audits and failing to deliver programs. While oversight of programs is important, NASA needs to be able manage. And the more challenging the project, the more it needs the flexibility and resources to manage well.

Consequences of No Action on the Recommendation: Additional constraints will make it more and more difficult for program managers to address program challenges, and could result in attitudes toward risk which discourage innovation.

At Mr. Bowersox's request, the Committee again considered reasons for supporting the Gateway concept and condensed the list of reasons from the first day's discussion to the list below:

Why Gateway?
We've already been to the lunar surface –why not do something more challenging, which will develop capability to go beyond the moon.

It all depends on why you want to go to the Moon. If you want to go fast like Apollo then direct may make sense. If you want to get to cislunar space and stay there, then Gateway is logical.
Gateway is for Mars exploration like Gemini was for Apollo –a program to develop new capabilities that will be required to go further into our solar system, and to develop the partnership that was built on ISS.
The cislunarorbiting platform (Gateway) isn't just about going to the lunar surface, or going to Mars, it's about both, and about going beyond.

Gateway makes it possible to use of all of the capabilities available in the United States and international partner countries to further human exploration –Orion, SLS, Commercial Launchers, International Launchers, International transport vehicles –and future elements provided by international and commercial partners. Gateway allows different elements to be built and operated by different partners, providing multiple options, and minimizing chances that any one partner will be in the critical path.

Gateway is not ISS around the moon. Gateway is intended to be procured a different way with much less cost – more like commercial cargo than either commercial crew or Orion.

Adjourn
Dr. Siegel thanked the Committee's staff for their support at the meeting. She noted that this would be the last meeting at which Mr. Frankel would take minutes for the Committee. She adjourned the meeting at 11:00 a.m.

NASA ADVISORY COUNCIL

Human Exploration and Operations Committee

MEETING
NASA Headquarters
Glennan Conference Center, Room 1Q39
300 E Street, SW
Washington, DC 20546

AGENDA

Thursday December 6, 2018

8:30-8:35	Call to order and Welcome	Mr. Ken Bowersox and Dr. Bette Siegel
8:30 – 9:30	Human Exploration and Operations Overview-	Mr. Bill Gerstenmaier
9:30– 10:30	ISS Update	Mr. Sam Scimemi
10:30- 11:00	Reliability statistics, planned versus actual, for ISS components	
11:00-12:00	Commercial Crew	Ms. Kathy Lueders
12:00-1:00	Lunch	
1:00- 2:00	Exploration Systems	Mr. Bill Hill
2:00- 3:05	Public Comments	
3:05- 4:30	Discussion and recommendations	

Friday Dec. 7

8:00- 8:05	Call to order	Dr. Bette Siegel
8:05-9:00	Gateway	Mr. Jason Crusan
9:00- 9:30	Power Propulsion Element Update	Dr. Michele Gates
9:30-11:00	Discussion and Recommendations	

11:00 Adjourn

Human Exploration and Operations Committee Membership
December 2018

Mr. Ken Bowersox, *Chair*	Former NASA astronaut and retired U.S. Navy Captain
Dr. Bette Siegel	NASA Headquarters *Executive Secretary*
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
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. Mark McDaniel	Partner at McDaniel and McDaniel Attorneys, LLC
Mr. Bob Sieck	Former Space Shuttle Launch Director
Mr. Gerald Smith	Former Deputy Director, Stennis Space Center, Georgia Tech Research Institute, Thiokol Propulsion, National Space Science and Technology Center in Huntsville
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, Room 1Q39
300 E Street, SW
Washington, DC 20546
December 6-7, 2018

MEETING ATTENDEES

HEO Committee Members:

Bowersox, Kenneth, *Chair*	Aerospace Consultant
Siegel, Bette, *Executive Secretary*	NASA Headquarters
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	Aerospace Consultant
Levin, Lon	SkySevenVentures
Longnecker, David	Association of American Medical Colleges
Lopez-Alegria	Commercial Spaceflight Federation
McDaniel, Mark	McDaniel & McDaniel Attorneys, LLC
Sieck, Robert *(via telecon)*	Aerospace Consultant
Voss, James	University of Colorado, Boulder

NASA Attendees:

Broadwell, Marguerite
Cruzan, Jason
Edwards, Ashley
Finch, Joshua
Finley, Patricia
Gates, Michele
Gerstenmeier, Bill
Herriman, Nicole
McAlister, Phil
McKay, Meredith
Mitchell, Jonathan
Pullen, Renee
Sarafin, Michael L.
Scimemi, Sam
Smith, Marshall
Vandehei, Mark
Whitmeyer, Tom

Other Attendees:

Hale, N. Wayne	NASA Advisory Council
Sanders, Patricia	Aerospace Safety Advisory Council

Telecon/Webex Attendees:

A.C. Charania	Blue Origin
Alfred Mendes	NASA
Allie Hannigan	Explore
Andrew Rowe	NASA
Barbara Adde	NASA
Bill Hill	NASA
Bill Peterson	self
Carol DeLuca	NASA
Carol Galica	NASA
Cheryl Warner	NASA
Chris Gilbert	VE Consult
Christine Pham	NASA
Daniel Lentz	n/a
Darrell Branscome	NASA consulting
David Eisenman	NASA JPL
David Millman	[not affiliated]
Denise Varga	GRC
Eracenia Kennedy	NASA
Eric Berger	ARS Technica
Erin Kennedy	GAO
Erin Mahoney	NASA HQ
Gale Allen	ASGSR
Gene Mikulka	Talking Space
Gregory Mann	NASA
Irene Klotz	Aviation Week
James Dean	Florida Today
James Lynch	NASA HQ
Jeff Foust	Space News
Jim Lochner	USRA
Jimi Russell	NASA
Jiri Hosek	[not affiliated]
Jonathan Mitchell	NASA
Katelyn Kuhl	NASA
Kathleen Boggs	NASA
Kelly O'Rourke	NASA HQ
Kevin Foley	Boeing
Kevin Metrocavage	NASA HQ
Kiersten White	NASA
Kurt Hack	GRC
Leo Enright	Irish Television
Linda Karanian	Karanian Aerospace Consulting
Lindsay Aitchison	NASA
Loren Grush	The Verge
Lynne Loewy	NASA
Madhu Thangavelu	University of Southern California
Magdiel Santana	NASA

Marc Seivert	NASA onsite support contractor
Marcia Smith	Space Policy Online.com
Margaret S. Race	[not affiliated]
Marguarite Broadwell	NASA
Mark Seaver	NASA contractor
Mary Faller	NASA
Maryann Chevalier	NASA
Michael Barrett	NASA Glenn
Mike Curie	Commercial Crew Program
Patricia Moore	NASA
Patrick Besha	NASA
Phillip Sloss	NASA Space Flight.com
Rick Irving	NASA
Robyn Gatens	NASA HQ
Ryan Faith	House Science Committee
Sam Gunderson	Blue Origin
Stefan Coburn	Blue Origin
Stephen Clark	Space Flight Now
Stephen Moran	Leidos Company
Stephen Ryan	NASA
Tanya Waller	GAO
Tara Ruttley	NASA
Tony Reichardt	Air & Space Magazine
Zachary Pirtle	NASA

Human Exploration and Operations Committee
NASA Headquarters
Glennan Conference Center, Room 1Q39
300 E Street, SW
Washington, DC 20546
December 6-7, 2018

LIST OF PRESENTATION MATERIAL[1]

1) Extending Human Presence into the Solar System [Gerstenmaier]
2) International Space Station Status [Scimemi]
3) International Space Station Status Maintenance Trends [Scimemi]
4) Exploration Systems Development Status [Whitmeyer] Tom Whitmeyer, Assistant Deputy Associate Administrator for Exploration Systems Development
5) Commercial Crew Program Status [McAlister]
6) Status of Gateway Power and Propulsion (PPE) [Gates]
7) Gateway Update [Crusan]
8) Management Memorandum [Gerstenmaier]

[1] Available at: https://www.nasa.gov/directorates/heo/nac-heoc