National Aeronautics and Space Administration
Washington, DC

NASA ADVISORY COUNCIL

Human Exploration and Operations Committee

March 28-29, 2017

NASA Headquarters
Washington, DC

MEETING MINUTES

_____
Kenneth Bowersox, Chair

_____
Bette Siegel, Executive Secretary

NASA Advisory Council
Human Exploration and Operations Committee Meeting
NASA Headquarters
Washington, DC
March 28-29, 2017

MEETING MINUTES
TABLE OF CONTENTS

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

NASA Advisory Council
Human Exploration and Operations Committee Meeting
NASA Headquarters
Washington, DC
March 28-29, 2017

Tuesday, March 28, 2017

Call to Order, Welcome, and 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 9:30 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. He introduced Dr. Patricia Sanders, Chair of the NASA Aerospace Safety Advisory Panel (ASAP). Mr. Bowersox noted that he had been away from the Committee while serving as the Acting Chair for the NAC. He thanked Mr. Wayne Hale for filling in as Acting Chair for the Committee during that time.

Human Exploration and Operations Mission Directorate

Mr. Bowersox introduced Mr. William Gerstenmaier, HEO Mission Directorate (HEOMD) Associate Administrator (AA), who briefed the Committee on the status of the Directorate.

Mr. Gerstenmaier explained that from an overall HEO standpoint, the new Administration has been positive. He noted that the Nation's goal for space exploration is to lead an effort that expands human presence deeper into the solar system through a sustainable human and robotic space flight program. He presented a new chart entitled "Exploring Space in Partnership." The chart showed three segments for the Journey to Mars. The "Now" segment calls for using the International Space Station (ISS). The "2020s" calls for operating in the lunar vicinity. The "2030s" segment calls for leaving the Earth-Moon system and reaching Mars orbit. There are five phases on the chart. Phase 0 is for exploration systems testing on the ISS to demonstrate key capabilities and operations and for fostering an emerging commercial space industry in low Earth orbit (LEO). It includes determining whether lunar resources will be available. Lunar orbiter and impact missions already conducted show that volatiles are present. Phase 1 is for conducting missions in cislunar space and assembling the Deep Space Gateway (DSG) and Deep Space Transport (DST). Phase 2 is for developing the DST and conducting a Mars-verification mission. Phases 3 and 4 will be missions to the Mars system and to Mars' surface. Mr. Gerstenmaier noted that Phase 4 now includes, at the Committee's suggestion, Phase 4a for robotic preparatory missions and Phase 4b

for Mars human-landing missions. He noted that the Administration's FY18 Budget Blueprint cancels the Asteroid Redirect Mission, though key technologies such as solar electric propulsion will be carried forward into the emerging cislunar architecture.

Mr. Gerstenmaier reviewed the NASA Transition Authorization Act of 2017. He explained that the goals and objectives in the Act are consistent with NASA's current goals. He cautioned that the program is in a very critical phase and that budget certainty for hardware is essential.

Mr. Gerstenmaier provided details on the objectives for Phases 0, 1, and 2. He described the DSG. It is intended to provide an ability to support multiple NASA, U.S. commercial, and international partner objectives in Phase 1 and beyond. It can support activities on the Moon's surface and can be moved to a higher elliptical orbit to support the Mars missions. It is intended to be multi-decadal and to serve only as a transit station or gateway. Mr. Bowersox observed that the DSG could provide additional safety for working on the lunar surface. Mr. Gerstenmaier cautioned that the DSG maneuvers very slowly and would take several weeks or months to be relocated because it relies on Solar Electric Propulsion (SEP). Mr. Bowersox suggested that it could provide a safe-haven refuge for crew returning from the Moon if, with adequate planning, it was moved to be in the proper position. In response to a question from Mr. Leroy Chiao, Mr. Gerstenmaier explained that one DSG would be sufficient. He added that the DSG should be viewed as infrastructure for an interplanetary highway that would be developed with NASA's international partners. He noted that there would be an early emphasis on defining the Gateway Power Propulsion Bus, the Gateway Habitat, and a logistics strategy. Later elements to be refined are an airlock and the DST. Mr. Gerstenmaier reviewed a chart showing the Phase 1 Plan. The intention is to establish deep-space leadership through development of the DSG and prepare for DST development. Mr. Gerstenmaier noted that Exploration Mission (EM)-1, originally intended to fly with no crew, is being studied for a crew complement. That would create additional risk for safety, schedule, and budget. The next Space Launch System (SLS) flight may be used for the Europa Clipper mission. Using the SLS would enable the Clipper to fly directly to Europa without having to fly around Venus for a gravity assist. HEOMD is working on this mission with the Science Mission Directorate (SMD). There are two planetary launch windows for Clipper—2022 and 2023. Once selected, that mission would be locked in and have priority over other missions.

Mr. Gerstenmaier reviewed a chart showing the work to be done during Phase 2 and Phase 3. That work looks ahead to the "shakedown cruise" and the first crewed missions to Mars. He described the DST functionality. It provides habitation and transportation needs for transporting crew into deep space, including supporting human Mars-class missions. It will be designed for a four-person crew on 1,000 day missions in deep space. The shakedown cruise will be performed in the lunar vicinity. The DST would be launched in a single SLS flight. It would have to be built on the ground in one piece to keep its weight down. Dr. Chiao suggested undocking the DST from the DSG during the shakedown cruise. Mr. Gerstenmaier agreed with the suggestion and stated that it should be studied. Mr. Bowersox observed that the DST is not limited to Mars, and Mr. Gerstenmaier agreed.

Mr. Gerstenmaier concluded his presentation with a chart showing how NASA is leading future human exploration.

Mr. Bowersox thanked Mr. Gerstenmaier for his presentation and noted that Mr. Gerstenmaier would be providing the same presentation to the NAC at its upcoming meeting.

Exploration Architecture Planning

Mr. Bowersox introduced Mr. James Free, Deputy AA, HEOMD.

Mr. Free reviewed a chart on the engineering integration process. The process is guided by and feeds into NASA's integration functions and needs. He explained that an integration function is needed across HEOMD to connect top-level goals, strategic principles, and objectives. The result is common and documented guidelines, assumptions, and design parameters against which elements can be evaluated and considered. He noted that international partnerships are needed for success, and NASA needs to look at new partnerships. In response to a question from Mr. Gerald Smith, Mr. Free stated that NASA's international partners have begun to indicate at ISS meetings their interest in participating in the DSG and DST. In response to a question from Dr. Chiao, Mr. Free explained that it would be possible for Blue Origin, or other companies or the internationals to participate in the DSG and DST.

Mr. Free reviewed the chart entitled "Exploring Space in Partnership," showing Phases 0, 1, 2, 3, 4a, and 4b for sending humans to Mars. He described the strategic principles for sustainable exploration and reviewed the phases for human space exploration from the ISS to the surface of Mars. He stated that NASA still has a goal to send humans on a Mars orbit mission in 2033, which may include a Venus flyby. Mr. Free discussed the exploration objectives for Phases 0, 1, and 2. He explained that the DSG would be crew-tended, which means that crew would not be on board all the time. Mr. Gerstenmaier emphasized that the chart on HEO implementation principles is important and contains many critical items. Mr. Free added that the principles apply to all of HEOMD, not just for lunar or Mars missions, and represents an attempt to capture Mr. Gerstenmaier's thoughts.

Mr. Tommy Holloway asserted that the longer NASA subsidizes commercialization of space, the more likely commercialization will become another bureaucracy, rather than being truly commercial. He stated, "It will become just another way to pay a contract." Mr. Gerstenmaier agreed and said that if the government is the only paying customer, then it is basically a government program. In response to a question from Ms. Shannon Bartell, Mr. Free responded that the DSG would not be a large vehicle and would not be permanently crewed. There would be some science performed on board, and there could be a science airlock. In response to a question from Mr. Bowersox, Mr. Free explained that there would be a two-year cadence for human missions to Mars. When Venus is not in alignment, a different route would be needed. Mr. Gerstenmaier explained that EM-1 and EM-2 would have very specific launch windows even to get to the Moon. He commented that the concept for the current plan has merit and that NASA understands the trades in the concept. As the concept becomes more public, he anticipates that academia and others will initiate independent analyses and studies that should lead to greater efficiencies and refinements.

Mr. Free reviewed a chart showing the relationship between NASA and HEOMD's strategy, principles, and objectives. He presented a chart showing how HEOMD implementation principles drive architecture, hardware, and mission trades and decisions.

Mr. Free explained that HEOMD develops its design guidelines and implementation principles in meetings with design teams and the HEOMD Senior Management Team. He noted that the DST will have a 1,000-day capability and must be able to fit within the SLS cargo-faring diameter, because NASA wants to launch the DST fully assembled. He reviewed HEOMD's implementation principles and discussed sample architecture guidelines for Phases 0, 1, and 2, as well as sample decisions.

Mr. Bowersox observed that a lot of the work seems to have started with the Evolvable Mars Campaign. Mr. Free agreed. Mr. Bowersox thanked Mr. Free for his presentation.

ISS and LEO Commercialization

Mr. Bowersox introduced Ms. Robyn Gatens, Deputy Director, ISS, HEOMD, who briefed the Committee on the status of the ISS. Ms. Gatens described the crew for Increment 50 and reviewed recent launch, landing, and extra-vehicular activities (EVAs). She explained that NASA groups EVA tasks together because it saves on crew time. She added that robotics allowed NASA to avoid the need for seven spacewalks. Ms. Gatens reviewed charts on ISS crew-time utilization and research statistics. She noted that 304 investigations were conducted during increments 51and 52 and that approximately 2,276 investigations have been completed to date. She described the Sun Monitoring on the External Payload Facility of Columbus (SOLAR) investigation that measures changes in the solar flux. The mission originally was planned to be a 1.5-year mission and has lasted 9 years.

Ms. Gatens reviewed charts on time usage, by sponsor, for Increments 47-48 and 49-50. She described two EVAs on Increment 50 to replace batteries. She reviewed the plans for upcoming EVAs. Ms. Gatens presented a chart on the total consumables available on board the ISS. She described an ammonia leak in the External Active Thermal Control System (EATCS) that has been trending since 2013. In response to a question from Mr. Hale, Ms. Gatens explained that the exact source of the leak has not been found. Dr. David Longnecker asked whether chemical sensors have been used to find the source of the leak during EVA. Ms. Gatens responded that there had only been a visible check during an EVA (the Robotic External Leak Locator was used to estimate the proximate source of the leak prior to the EVA but cannot be used during EVA because EVA metabolic products will confound the readings).

Ms. Gatens described the results from the recent SpaceX-10 mission and the planning status for SpaceX-11. She noted that the SpaceX-11 mission would be the first re-use of a Dragon capsule. Ms. Gatens discussed the successful Orbital ATK (OA)-5 Antares return-to-flight mission. She reviewed the mission planning status for the OA-7 Mission and noted that an anomaly in the Atlas booster is under investigation. She described the successful Japan Aerospace Exploration Agency's (JAXA's) H-II Transport Vehicle (HTV)-6 mission, which delivered lithium-ion batteries to the ISS.

Ms. Gatens reviewed the status of the Commercial Resupply Services (CRS)-2 contract. Those contracts were awarded on January 14, 2016, to OA, Sierra Nevada Corporation (SNC) and SpaceX. CRS-2 missions are planned for launch beginning in 2019.

Ms. Gatens presented a chart on the ISS integration status of crew vehicles. She provided an update on LEO commercialization activities and noted that NASA has initiated a study to define long-term research and utilization requirements for LEO. She noted that NASA had received 12 responses to its Port Request for Information (RFI), describing what the responders would do with the port and how it would help commercial space development. She explained that the commercial space industry would like to see a government forecast on the government's LEO requirements so that industry could begin to develop commercial cases for LEO platforms.

Mr. Robert Sieck inquired about the status of orbital debris. Mr. Gerstenmaier responded that orbital debris is what had been predicted. He added that the ammonia leak is not an immediate problem. NASA had enough ammonia on board to last through 2028 despite the current leak. Mr. Gerstenmaier noted that the Canadian robotic arm has made it possible to use fewer EVAs than originally predicted.

Mr. Bowersox thanked Ms. Gatens for her presentation.

Space Life and Physical Sciences Research and Applications

Mr. Bowersox introduced Dr. Craig Kundrot, Director, Space Life and Physical Sciences Research and Applications Division (SLPSRA), HEOMD, who briefed the Committee on recent developments in the division. He explained that the SLPSRA portfolio is guided by the National Academy of Sciences' (NAS) Decadal Survey, which covers research that enables space exploration and research enabled by access to space.

The SLPSRA vision is to "lead the space life and physical sciences research community to enable space exploration and benefit life on Earth." Its mission is to enable exploration to expand the frontiers of knowledge, capability, and opportunity in space, and to pioneer scientific discovery in and beyond LEO. Dr. Kundrot discussed the open science concept, where a team of scientists is used, rather than a single principal investigator (PI). It is intended to maximize community participation in the formulation of investigations where feasible. The "Twins Study" is a good example of an investigation using the open science concept. Dr. Kundrot described the partnerships that are needed to enable exploration—the "pull"—and to pioneer scientific discovery—the "adopters." He discussed a chart on capitalizing resources at and below LEO.

Dr. Kundrot explained that SLPSRA has three components: The Human Research Program (HRP), Space Biology, and Physical Sciences. He reviewed a chart summarizing the human risks of space flight. The altered gravity field is the most significant risk, followed by radiation. Dr. Kundrot reviewed a chart showing how life science differs from engineering. He described how the body's physical accommodations to weightlessness cause problems that lead astronauts to faint upon returning to Earth. He reviewed recent advances in biotechnology. He discussed omics, which is molecular data collection, and noted that the ability to obtain that data has been increasing "super-exponentially." He noted that the cost of sequencing the human genome has been falling

much faster than Moore's Law and that this generation may see human-directed evolution of humans.

Dr. Kundrot noted that Space Biology seeks answers to one of the most fundamental questions of life: "What happens to life from Earth, beyond Earth?" He explained that the constant acceleration of gravity for 3.5 billion years has shaped every aspect of Earth's biosphere. He presented a chart on Space Biology's purpose and goals. He reviewed the Space Biology areas of study, which are based on the Decadal Survey recommendations. He described the Veg - 03A experiment on the ISS, which tested the repetitive harvest technique "cut-and-come-again." It enabled the ISS crew to enjoy multiple harvests from a single lettuce plant. Dr. Kundrot discussed a chart on the gravity dose response curve.

Dr. Kundrot explained that Physical Sciences research is conducted in biophysics, materials science, fundamental physics, complex fluids, fluid physics, and combustion science. He presented charts on the Physical Sciences areas of study, which are based on the Decadal Survey recommendations. He described the Cool Flames Investigation (CFI) and explained that cool flames chemistry is not well understood. Dr. Kundrot described the Zero Boil-Off Tank (ZBOT) investigation into mass and thermal transport and phase change aspects of cryogenic tank pressurization and pressure control in microgravity. He described the soon to be launched Cold Adam Laboratory (CAL), which investigates Bose Einstein Condensation.

Dr. Pat Condon asked what NASA was doing to get "non-geeky" supporters in Congress excited about the work at SLPSRA. Dr. Kundrot responded that there is "a portfolio of answers" to that question. He cautioned that it is easy to oversell unless one is rigorous and accurate about claims. Ms. Nancy Ann Budden advised that it is important for NASA to communicate its mission and accomplishments to the public in a way that is sustainable. She added that alternative applications are one way to achieve that goal. Mr. Bowersox asked about recent developments in protein crystal growth. Dr. Kundrot responded that the Center for the Advancement of Science in Space (CASIS) is doing most of the work in that activity. Mr. Bowersox noted that there had been a problem finding crystals that are strong enough to survive re-entry and asked whether there were plans to work on that problem. Dr. Kundrot responded that re-entry forces are not a major concern for most proteins and that there is a little bit of research aimed at determining which proteins crystals can benefit the most from growing in microgravity.

Mr. Bowersox thanked Mr. Kundrot for his presentation.

Commercial Crew Program

Mr. Bowersox introduced Ms. Kathy Lueders, Program Manager, Commercial Crew Program (CCP). Ms. Lueders briefed the Committee on the status of the CCP Commercial Crew Transportation Capability (CCtCap) and Commercial Crew Integrated Capability (CCiCap) contracts. She reviewed a chart showing program progress. Post certification missions three through six have been awarded for both SpaceX and Boeing. Eight CCP missions are now in process: two test flights and two post certification missions for each provider. The CCP is refining the flight test mission definition, defining interactions with the ISS, and building mission management strategy. All flight tests will dock with the ISS, which necessitates strong tri-lateral integration between the ISS, CCP,

and the providers. The CCP is collaborating with multiple agencies to facilitate U.S. commercial crew space transportation. Some of those agencies include the Federal Aviation Administration (FAA), the National Telecommunications and Information Administration (NTIA), the Federal Communications Commission, and the U.S. Air Force.

Ms. Lueders reviewed a chart showing CCP's top safety and programmatic risks. The top three programmatic risks are requirement changes, Department of Defense (DoD) search and rescue posture, and ability to close the loss of crew (LOC) gap. The top safety risk is the ability to close the LOC gap. Mr. Sieck asked Ms. Lueders to characterize the stability of the requirements that are levied on the contractors. She replied that the baseline is 98 percent stable and that any new requirements would most likely come from the ISS. As an example, she added that the need to develop a response to an ammonia emergency is a new item. In response to a question from Mr. Bowersox, Ms. Lueders explained that the contracts are fixed-price contracts and that the contractors are entitled to compensation if there are changes made to the scope of the contract. Those costs would be negotiated. In response to a question from Mr. Bowersox, Ms. Lueders explained that due to the sensitive nature of proprietary information, the risks shown on the charts she presented are program-level risks encompassing the work of both providers. Mr. Bowersox noted that it may be necessary for the Committee to send a few members on a fact-finding mission to obtain information that cannot be presented in an open-FACA session. Ms. Ruth Gardner asked Ms. Lueders to discuss the LOC gap. Ms. Lueders explained that 1/270 was the original LOC requirement and had been derived from Constellation, which in turn was driven by the Space Shuttle. Mr. Hale noted that 1/65 was the LOC number at the end of the Shuttle and, based on a retrospective study, Space Shuttle Transportation (SST)-1 turned out to have been a 1/9 risk. Dr. Sanders explained that there is a large uncertainty band around the numbers.

Ms. Lueders presented a chart showing the CCtCap combined milestones through 2018. She reviewed charts showing recent accomplishments by both providers. She presented a chart showing CCiCap combined milestones and described recent accomplishments by the Sierra Nevada Corporation (SNC). She reviewed Blue Origin's recent accomplishments under its Commercial Space Capabilities Collaboration (CSCC) Unfunded Space Act Agreement (SAA).

Ms. Lueders reported that the CCiCap partners continue to advance integrated crew transportation system designs. Boeing and SpaceX are meeting contractual milestones and maturing their designs. They are actively building and testing hardware to inform the design, engaging in meaningful insight with NASA, and addressing important design challenges. They are providing increased insight opportunities for the NASA team. She noted that CCP has robust and efficient processes for certification that include addressing waivers and deviations. She acknowledged that there is significant work ahead in preparation for flight. Mr. Bowersox asked whether there were any risks that she worries about. Ms. Lueders responded that a program manager responsible for flying people without being worried would not be doing his or her job. Every system has technical issues and the CCP is working with the providers to develop strategies to work through those issues. The CCP and the providers must be vigilant and serious. Mr. Bowersox thanked her "for a great answer to a terrible question." In response to a question from Mr. Smith, Ms. Lueders responded that the launch dates for the next year were "pretty tough, but not impossible" and that "a lot of things have to go the right way." She noted that there is much testing to be done and not a lot of margin in the schedules, so it is very challenging. The providers

are trying to think of everything they can do to mitigate schedule risks. Mr. Bowersox commented that the ISS has mitigation in place through 2019 if the schedule slips and that Mr. Gerstenmaier has backups in place to avoid imposing undue pressure on the program. Ms. Lueders stated that the providers are making the changes necessary when hardware does not work. They are putting their name on the product. CCP is working with them and helping as much as possible, while keeping its footprint as small as possible. Mr. Bowersox asked whether the providers were getting rapid enough responses from the NASA team. Ms. Lueders responded that CCP, the ISS, and the providers have been working to establish the Program Certification of Flight Readiness (CoFR) process. Mr. Lon Levin applauded the fact that providers seem to be providing increased insight opportunities for the NASA team. Ms. Lueders responded that it is a balancing act and that the CCP must be mindful of is footprint.

Mr. Bowersox thanked Ms. Lueders for her presentation.

Public Comments

Mr. Bowersox invited comments from the public.

Mr. David Arkman, speaking from Seattle, Washington, introduced himself. He stated that it would be Earth Day on April. 22nd, and he asked whether the NAC is doing anything to promote Earth Day. He noted that some of the most eloquent responses to problems on Earth come from the astronauts and cosmonauts. He suggested that it would be helpful to have NASA be more involved in Earth Day. Mr. Bowersox thanked Mr. Arkman for his comments.

There were no other public comments.

Discussion and Recommendations:

Mr. Bowersox indicated that the next Committee meeting would probably be held towards the end of July at NASA Ames Research Center, at Moffett Federal Airfield in Mountain View, California. The winter meeting would be in November or December. (It has since been decided that the July meeting would be at Langley Research Center).

Mr. Bowersox explained that the Committee's findings and recommendations must be approved by the NAC and that Committee conclusions and observations do not require NAC approval. Mr. Bowersox reviewed the findings, recommendations, observations, and top concerns from the last Committee meeting. He noted that the NAC had had a 45-minute session with the new Administration's transition team. The transition team was very interested in the NAC's findings and recommendations on the Asteroid Retrieval Mission (ARM), commercial crew, and opportunities to accelerate SLS and Orion. In response to a question from Ms. Budden, Mr. Bowersox explained that concerns and observations go to the NAC and to anyone else who wants to read them. The procedure enables the Committee to speak to a wider audience without first obtaining NAC approval.

Dr. Sanders suggested that the Committee discuss the timing for an effort to extend the ISS from 2024 to 2028. Mr. Bowersox noted that NASA might not want it to go beyond 2024. Mr. Holloway

reported that Mr. Gerstenmaier needs to make the decision by 2020, and it is apparent that he wants it to be extended to 2028. Mr. Hale stated that the criteria for the decision should include the technology burn down chart, getting science completed to support exploration, and establishing a cadence of regularly flying humans on Orion and SLS. Mr. Gregory Williams stated that the commercial world needs an opportunity to mature capabilities. Mr. Bowersox noted that Russia intends to reduce its crew complement on the ISS to two crewmembers, which means that there is a potential for the U.S. to increase its crew complement to four crewmembers.

The Committee discussed LEO commercialization. Mr. Levin explained that the concept does not mean that private industry would be buying the ISS. It could mean that people would be building manufacturing plants in space that will not need to be human-tended. Mr. Hale noted that LEO commercialization is a goal from the last Administration, and he presumes it is a goal of the current Administration.

Ms. Bartell commented that the Committee had been asking for more details on the plan for exploration, and Mr. Gerstenmaier has provided the Committee with information about the DSG and DST. Mr. Bowersox stated that there has been a "shift and uptick" to the planning, and he would like to see more detail. Ms. Bartell noted that Mr. Gerstenmaier had not said anything about science and that a strategy for science is necessary. Mr. Bowersox stated that there would be opportunities to do science in space on the new platforms. Dr. Condon recommended that the Journey to Mars document needs to be replaced, and Ms. Budden seconded his recommendation. Ms. Bartell asserted that the new chart communicates better than the old "squid" chart. Mr. Bowersox observed that the squid chart worked well for people without technical backgrounds, and the new chart is great from an engineer's perspective. Ms. Budden commented that the new chart uses technical terminology that everyone can understand, and Mr. Bowersox agreed that it would be understood by the public.

Ms. Bartell observed that Mr. Gerstenmaier had not provided the rationale for the DSG and DST. Dr. Longnecker expressed concern over allowing the EM-1 schedule to slip and changing it to a crewed mission. He advised that NASA should launch the mission during the current Administration because when administrations change, agendas change. Mr. Chiao advised that it would be worth going forward with a crewed EM-1 if there were sufficient funding. Mr. Bowersox cautioned that the Committee did not have data about putting crew on EM-1. Dr. Sanders reported that the ASAP had found that putting crew on EM-1 would be more costly and risky because crew was not in the original plan. The ASAP concluded that a decision to make the change needed to have a compelling benefit. In addition, NASA should be upfront and transparent about the risk that it would be accepting.

Ms. Bartell recommended that the Committee designate one or more members to become educated in the CCP's technology, cost, and safety risks. Mr. Bowersox stated that the ASAP is chartered with responsibility for overseeing crew safety and should be trusted to do that job. Ms. Bartell asserted that the Committee's job "is larger than safety" and includes schedule and cost. Dr. Sanders advised that everything is related. Mr. Levin asserted that the Committee cannot be the second safety committee; rather, the Committee is tasked with watching things unfold and making sure that the program is on the right track. Mr. Bowersox stated that the Committee's action would be to get a few members access to the CCP's risk lists. Mr. Holloway explained that one of the top

problems is requirement changes. Dr. Sanders concurred and added that a requirements change is a risk to funding because the fixed-price contract must be modified by a change order. Mr. Bowersox stated that there are risks that the Committee is not seeing. Mr. Holloway cautioned that the Committee has no idea on how well Ms. Lueders is managing the CCP. Mr. Levin stated that it is the Committee's overarching function to ascertain whether the CCP alternative is working the way it had been planned. He asked whether the Committee had any insight into how Ms. Lueders was performing or whether the process was working. Dr. Sanders advised that it would be worthwhile for the Committee to examine how well the business model was performing. She noted that the business model is different for both providers. Mr. Levin recommended that examination be done by the Committee without being disruptive. Mr. Hale suggested that the providers be asked to brief their risks, rather than have NASA personnel brief what they think the providers' risks are. Mr. Bowersox stated that the Committee members' inputs could be helpful to the program. However, Mr. Levin asserted that the providers would contend that no help is needed.

Mr. Williams noted that the NASA Authorization Act includes a requirement for NASA to develop a roadmap by December 1, 2017. Mr. Hale commented that NASA has a "lousy telecon system" and "should be embarrassed" that it cannot provide good teleconferencing for a public meeting.

Adjourn

Dr. Siegel adjourned the committee meeting for the day at 5:27 p.m.

Wednesday, March 29, 2017

Opening Remarks

Dr. Siegel reconvened the committee meeting at 8:00 a.m. and introduce Mr. Bowersox.

Exploration Systems Division

Mr. Bowersox introduced Mr. William Hill, Exploration Systems Division (ESD) Deputy AA, who briefed the Committee on the status of the division. Mr. Hill reviewed a chart on ESD's top concerns:

- Integrated avionics and software verification and validation (V&V);
- Continuing Resolution (CR) and out-year funding uncertainty impacts to EM-1 and EM-2;
- Mobile Launcher (ML), Vertical Assembly Building (VAB), and Pad;
- European Service Module (ESM) delivery date erosion (now Fall 2017);
- Vertical Assembly Center (VAC) weld strength anomaly;
- SLS tornado damages assessment and recovery operations;
- Productions and operations (P&O) sustainability at one flight per year after EM-3; and
- EM-2 first crewed test flight risk and related mission planning.

Mr. Hill described the status of Orion. He discussed the EM-1 Launch Abort System (LAS), the EM-1 Crew Module, the EM-1 Crew Module Adapter (CMA), and the EM-1 Service Module. He discussed the Crew Module Structural Test Article (STA) and presented a slide showing it at the NASA Glenn Research Center's (GRC). He described work being performed on flight software development.

Mr. Hill reviewed the status of the SLS. He described the damage from the EF-3 tornado on February 7, 2017, with wind gusts from 136 to 165 mph. In response to a question from Ms. Gardner, he explained that repairs were being paid for with SLS funds and that a supplemental budget to cover the cost has been requested. Mr. Gerstenmaier stated that the tornado took a very damaging path through the facilities. Mr. Hill discussed the EM-1 integrated spacecraft payload element effort at NASA Marshall Space Flight Center (MSFC). He presented a chart showing the work being performed on the EM-1 stages. He described the SLS STA testing at MSFC.

Mr. Hill discussed the development of the EM-1 boosters at Orbital ATK in Utah and described the work on the EM-1 engines at NASA Stennis Space Center (SSC). At Dr. Chiao's request, Mr. Hill and Mr. Gerstenmaier described the challenges in obtaining new engine controllers from the vendor. Mr. Hill discussed software testing at the MSFC Software Test Lab.

Mr. Hill updated the Committee on the status of Ground Systems Development and Operations (GSDO) Program. He described umbilical production and testing at the NASA Kennedy Space Center (KSC) Launch Equipment Test Facility (LETF) and discussed the outfitting and checkout of the ML. He described the platform installation work being performed at the VAB and the upgrade design work at Pad 39B. All ten platforms have been installed in the VAB. Mr. Hill discussed the ground software being developed at KSC by the Ground Flight Application Software Team (GFAST), and he described the Spaceport Command and Control System (SCCS).

Mr. Hill discussed cross-program systems integration (CSI). He presented a chart on CSI technical performance and recent major accomplishments. He reviewed CSI's top technical issues. He noted that the list is updated daily and that the team uses the list to work off the issues. Mr. Hale questioned the need for the 120-day SLS pad stay requirement. Mr. Smith noted that the Orion's pad stay requirement is 30 days and suggested that there was a disconnect. Mr. Hill responded that a better job should have been done in scrubbing the Constellation requirements. Mr. Hill described the major CSI independent assessments in progress. Mr. Hale suggested that there should be a single document identifying all the panels that participate in reviews. Mr. Hill agreed to include that document in the implementation plan. Mr. Holloway advised that the number of panels should be limited. Mr. Hale expressed concern about integration at the top level.

Mr. Bowersox thanked Mr. Hill for his presentation.

Cislunar Habitation, Environmental Control, and Life Support System

Mr. Bowersox introduced Mr. Jason Crusan, Director, Advanced Exploration Systems (AES) Division and Ms. Robyn Gatens, Deputy Director, ISS.

Mr. Crusan presented the chart entitled "Exploring Space in Partnership." He explained that "habitation capability" means the overall systems to enable the crew to live and work safely in deep space. He reviewed a chart on the space habitation development strategy and noted that NASA is now moving to the development of detailed ground prototypes. Mr. Crusan emphasized it is a critical time to solidify the international contribution potential. Proving Ground Phase 0 would be used for systems development and testing on ISS and in LEO. Proving Ground Phase 1 would be used for deep-space testing. Proving Ground Phase 2 would be used for deep-space validation. He discussed the three-phase approach that would be used for habitation development. Phase 1 ends with industry development concepts. Phase 2 ends with domestically developed ground prototype modules, identified standards, and common interfaces, defined contributions from International Partners, and definition of what will be supplied as government furnished equipment. Phase three begins with determining the acquisition approach including domestic and international partnerships and proceeding through the acquisition of the flight units of all of the elements required.

Mr. Crusan presented a chart showing an overview for NextSTEP habitation development. Four significantly different concepts for cislunar habitation have been received from Lockheed Martin, Bigelow Aerospace, Orbital ATK, and Boeing. He discussed the approach used for developing standards. It is acquisition strategy neutral. NASA has established a Habitation Capability Standards Working Group led by the ISS and AES divisions with support from NASA's Technical Authorities (TAs) to design a suite of standards. The Future Capabilities team is working with NASA's international partners. The HEOMD AA will be the approving authority for the standards. Mr. Crusan explained that NextSTEP Broad Agency Announcements (BAAs) would be used to obtain cross-cutting GFE for the environmental control and life support system (ECLSS), avionics, soft goods testing, window material, radiation analysis, exercise equipment, and ground testing. He explained that the NextSTEP Phase 2 habitation capability goal is to develop a deep-space habitat for ground-based testing by 2018, while simultaneously stimulating commercial habitat development in LEO. He presented a chart on the NextSTEP execution plan.

Mr. Crusan described the NextSTEP Phase 2 Bigelow Aerospace 330 cubic meter (m^3) habitat that includes a concept that attaches to the ISS as a testing platform for deep-space exploration technologies and procedures. He reviewed the NextSTEP Phase 2 key attributes, design teams, technical approaches, and objectives used by Boeing, Lockheed Martin, Orbital ATK, and SNC. Mr. Cruzan described a NextSTEP Phase 2 NanoRacks study to look at the feasibility of converting spent rocket upper-stages into habitats while in space. He presented a slide on work currently being performed on developing deep-space habitation systems. He described the Bigelow Expandable Activity Module (BEAM), which is a two-year demonstration that was installed on the ISS in May 2016. The module has performed as expected. Radiation readings indicate galactic cosmic ray exposure is the same as other Space Station modules. The module is slightly warmer than predicted but does not pose any risk to the crew.

Mr. Crusan described the life support systems currently in development for demonstration on the ISS. They include an aerosol sampler, urine processor, spacecraft atmosphere monitor, and demonstrator for ionized inert gas. He described NextSTEP Phase 2 life support system development contracts to be awarded to Dynetics, UTC Aerospace Systems, and Orbitec. He presented a slide on radiation sensors developed by RadWorks. He described the Radio Frequency Identification Enabled Autonomous Logistics Management (REALM)-1 that will be used to track inventory and quickly locate items that are missing.

Mr. Crusan discussed several Spacecraft Fire Safety Experiment (Saffire) elements. Those experiments are used to assess flame spread of large-scale microgravity fire; verify oxygen flammability limits in low gravity; demonstrate spacecraft fire detection, monitoring, and cleanup technologies; and provide data to validate models of realistic spacecraft fire scenarios.

Ms. Gatens reviewed the status of work being performed by the System Maturation Team on ECLSS. She presented charts identifying specific deep-space habitation system objectives and a graphic diagramming exploration ECLSS to show the complicated interrelationship between the system components. She reviewed a schedule showing ECLSS and environmental monitoring capability gaps. She presented a chart showing the Exploration ECLSS Roadmap. Ms. Gatens described current development efforts to evolve the ISS ECLSS into the Exploration ECLSS including carbon dioxide removal, oxygen generation, oxygen recovery, urine, water, and brine water processing, and managing solid waste. She discussed long-wear clothing recently demonstrated on the ISS. In response to a question from Ms. Budden, Mr. Crusan explained that the clothing is commercially available "off-the-shelf" and that natural wool is better than any synthetic fiber. He added that the crew could clean clothes using a small clothes washer but that has to be traded vs. just disposable clothing. Mr. Bowersox commented that crews are going to be looking for things to do on the way to Mars anyway, so they may as well do their own laundry. Dr. Chiao, also a former astronaut, reported that it is reasonable for astronauts in space to wear their clothing for longer periods of time than typically seen on the ground, and that some of the clothing could be used for exercise after being used for normal wear.

Ms. Gatens discussed repurposing packaging and cargo bags. She described how the REALM-1 had successfully responded to an unplanned real-time ISS request to locate a missing cargo bag. Ms. Gatens reviewed the status of equipment under development for atmosphere and water monitoring. She described the process used to integrate on the ISS the equipment under development for exploration ECLSS.

Mr. Bowersox thanked Mr. Crusan and Ms. Gatens for their presentation.

In-space Power/Propulsion

Mr. Bowersox introduced Dr. Michele Gates, Program Director, ARM. Dr. Gates presented the chart entitled "Exploring Space in Partnership" and explained that the DSG and the DST will be developed during Phases 1 and 2. She reviewed the requirements from the ARM and the Asteroid Redirect Robotic Mission (ARRM) for a high-power, high-total impulse SEP system. Mr. Bowersox noted that elements critical for exploration had been retained from the ARM.

Dr. Gates described SEP risk reduction thruster testing that NASA conducted on SEP Technology Demonstration Unit (TDU)-3 in Vacuum Facility (VF)-6. The Safety and Mission Assurance (S&MA) Directorate is tracking six Developmental Anomaly Reports (DARs) from the tests.

Dr. Gates reviewed the contributions from the ARM solar electric propulsion (SEP) team. She explained that advanced SEP systems are part of the foundation for human exploration plans, including ultimately a transportation system for human exploration to and from the Mars system. Advanced electric propulsion systems, compared to chemical systems, require 5 to 10 times less

propellant mass for equivalent missions. She presented a chart on ARM SEP technology demonstration contributions. Dr. Gates described ARM's scalability for deep-space human exploration and noted that the DST would add chemical propulsion capability to the solar propulsion capability. Mr. Bowersox commented that chemical propulsion is required for the crew. In response to a question from Dr. Sanders, Dr. Gates stated that the first SEP flight test would be on EM-2.

Mr. Bowersox thanked Dr. Gates for her presentation. He commented that it is important to acknowledge the great work from ARM that is going to be included in the plans for future deep space exploration.

Summary

Mr. Gerstenmaier encouraged the Committee to think about the ISS beyond 2024. He explained that the decision to extend the ISS to 2024 was good when it was made, and he noted that it had been made early in the process. He asserted that the ISS is part of exploration and should not be considered a funding source for other programs. Mr. Bowersox advised that the decision to extend the ISS beyond 2024 needs to be made soon to maximize effective utilization of ISS. He explained that a commercial company's willingness to utilize the Station lessens as the expiration date for the Station gets closer. Accordingly, there are tremendous advantages to deciding to extend to 2028 with less than perfect data. Mr. Holloway asked whether NASA could execute exploration with current funds plus funds from the ISS. Mr. Gerstenmaier responded affirmatively. He added that by 2028, the ISS would be competing with or discouraging commercial activity in LEO. By that time, science would be performed on the Moon or in orbit around the Moon, and it would be time for the government to consider deorbiting the ISS. In response to a question from Mr. Chiao, Mr. Gerstenmaier stated that launches represent more than 50 percent of the ISS's costs and that it is important to think about the transition from the ISS. He explained that there are contingency plans to deorbit the Station and that it would be necessary to stop using the ISS a year before it is deorbited. He noted that the Russians may want to repurpose some of their modules and that in 2023, the Chinese will launch their station. He asked a rhetorical question, "Is this the time to cede and hand over global leadership for spaceflight?"

Mr. Holloway observed that money from Station would be needed for exploration and asked whether NASA could reduce the cost for running the facility. Mr. Gerstenmaier responded that the sustaining cost for Station is $1 billion (B) per year. Mr. Smith asserted that most of what would be needed from Station for exploration can be obtained by 2024. Mr. Bowersox responded that if the ISS ends in 2024, not much would be accomplished during the last year. He advised that HEOMD focus on how to increase the Station's benefits and encourage the private sector to commercialize LEO for a profit. In response to a question from Mr. Holloway, Mr. Gerstenmaier explained that NASA is going to try to transfer the ISS transportation costs to the user. He cited CubeSats as an example. He stated that NASA is holding back the CubeSat market by providing subsidies and that continuing to do so would inhibit the commercial sector.

Ms. Budden noted that the Chinese space station would be considered a "persistent stare" in the sky and is a "huge national security issue" that is a major topic in the DoD. Mr. Gerstenmaier explained that the issue of how a commercial space station would compete with a government

space station in LEO is a matter that leadership must resolve with less than perfect data. In response to a question from Dr. Condon, Mr. Gerstenmaier explained that the process for making the decision on extending the ISS to 2028 is "murky." The NASA Authorization Act contains four pages of guidance on reports that he is required to submit on the transition. Mr. Sieck asked what percentage of the ISS currently relates directly to long-duration space flight. Mr. Gerstenmaier responded that he would consider the matter and provide a written answer to the question, rather than speculate. Mr. Bowersox stated, "every second of crew time applies to exploration."

Mr. Holloway expressed concern over the integration function because it is not well understood. He asserted that a system and accountability for the work is needed. Mr. Gerstenmaier responded that the level 2 integration function was intentionally kept small, and he agreed that in some areas it has not been working well. He will provide an update on it in a future presentation. Dr. Sanders reported that the ASAP had been concerned about integration and has reached a much better comfort level. Mr. Bowersox suggested that some Committee members conduct insight visits. Ms. Bartell explained that there is "fear that things may have been missed." Ms. Ruth Gordon advised that there is an advantage in having two people who interface make sure that they sit down and agree on what needs to be done for integration. Mr. Gerstenmaier responded that he has added additional integration into the models to be proactive and reactive. There may be areas that can be improved; however, there is insufficient budget to do everything he would like to do.

Mr. Gerstenmaier explained that oversight is provided by standing review boards, Congressional panels, the NASA Inspector General (IG), the General Accounting Office (GAO), potemtially the National Space Council (NSC), the media, the public, the NAC, and the HEO Committee. He has had to fence off programs from oversight because his team is spending too much time briefing oversight committees and not doing the day-to-day work. He asked the Committee to consider whether streamlining the oversight might be appropriate. He cautioned, "if everybody is in charge, nobody is in charge" and suggested that it would be a good area to provide a recommendation for the Administrator. Mr. Holloway complained that the Committee is presented "the same stuff every time we come." Dr. Sanders advised that the meetings have intangible value because they give Mr. Gerstenmaier the opportunity to present to a friendly audience. Ms. Budden concurred and stated that Dr. Sanders was describing "the trusted agent model." She added "hopefully you look at us as trusted agents and as patriots." Mr. Gerstenmaier agreed and stated that the process makes the directorate stronger. Mr. Hale commented that the Committee " sees things over and over again and also sees progress." Mr. Gerstenmaier explained that the Deep Space Gateway and the Deep Space Transit are separate entities and that NASA needs something flown in space before ECLSS and SEP are perfected. He noted that a lot of equipment was being configured on the ISS that had not been in the original requirements document.

Mr. Bowersox thanked Mr. Gerstenmaier for his presentation.

Discussion and Recommendations

Mr. Bowersox invited Committee members to offer suggestions for Committee findings or recommendations. He explained that findings and recommendations must be approved by the NAC and are then forwarded in a letter to the Administrator and the AAs. Recommendations must be actionable by the Administrator.

Ms. Budden advised that Mr. Gerstenmaier's comment on the need to streamline advisory committees was important. Ms. Bartell reminded the Committee that one issue raised by program managers had been oversight. Mr. Bowersox stated that the Committee, at its past July meeting, had issued advice on the number and intensity of reviews.

Mr. Bowersox noted that the current plans for the ISS call for it to be terminated in 2024. He explained that the ISS would likely be needed until 2028. Mr. Michael Lopez-Alegria observed that the drivers for 2028 include commercialization milestones. He asserted that it would be difficult for any commercial company to provide a LEO commercial facility while the government was providing the ISS as a free facility.

Dr. Sanders advised that the DSG should not become an ISS around the Moon. Ms. Bartell observed that the commercialization of LEO sometimes comes across as commercialization of the ISS. She believes it is a communication issue.

The Committee reviewed and modified its standing list of concerns and observations.

Committee Observations

- The current transition to a new presidential administration and a new Congress seems to be going well. The HEO Committee commends the NASA team for their good work in preparation for the transition. The recent Congressional approval signature by the President of NASA's latest Authorization is an important step toward successful completion of NASA's HEO programs.

- NASA continues to add detail to plans for exploration in cislunar space and beyond. The HEO Committee was pleased to see the amount of additional detail in exploration mission planning that was evident at this session and concurs with the HEO AA that the time is right to make decisions that will focus the development effort for the planned series of cislunar exploration missions.

- If NASA decides to put crew on EM-1, it is important to ensure that the benefit warrants the risk level. It is also critical that the mission receive adequate funding and schedule flexibility to complete critical test activity prior to carrying crew aboard SLS and Orion, as well as eliminating impacts to the content and scheduled dates of later missions.

- The Journey to Mars document was a valuable attempt to communicate the rationale for NASA's future plans to move from Earth orbit, to cis-lunar space, and then on to Mars. It would be helpful to replace this document with one that describes current plans for missions in cislunar space and beyond. The most recent NASA Authorization Act has a requirement for an exploration road map to be completed by December 1, 2017, that could be a good candidate for replacement of the Journey to Mars publication.

- ISS is a critical test bed for development of systems that will be used for deep-space exploration. While projections show that the work should be complete by 2024, the Committee believes that it is likely that exploration development work on ISS will need to be continued until 2028 or later.

Committee Concerns

- Budget uncertainty and lack of flexibility in use of funds continues, and now has greater potential for program disruption as SLS and Orion get closer to launch.

- The DSG could be capable of other deep-space missions, in addition to its prime mission as a node for development and staging of the DST. The Committee is concerned that requirements for the Gateway may grow excessively during the development phase and encourages the HEO team to maintain focus on the prime mission when developing the Gateway's system requirements.

- Bureaucratic processes that NASA imposes on itself do not always add value to balance their load on the organization and are a threat to the accomplishment of NASA's exploration mission.

- The number and intensity of current reviews of the HEO programs are not helpful and use too many precious resources.

- Low SLS and Orion Launch rates pose future risks for proficiency of the operations team and reduce program resilience in the event of mission failure.

Mr. Bowersox thanked the Committee members for their participation at the meeting. Dr. Siegel thanked Ms. Renee Pullen for her hard work and stated that she had done an excellent job in her first meeting as Committee Administrative Officer.

Adjourn

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

Tuesday March 28, 2017

NAC HEO COMMITTEE PUBLIC MEETING

9:30 – 9:35	Call to Order, Welcome & Opening Remarks	Mr. Ken Bowersox & Dr. Bette Siegel
9:35-10:30	Human Exploration & Operations Mission Directorate	Mr. Bill Gerstenmaier
10:30-11:30	Exploration Architecture Planning	Mr. Jim Free
11:30- 12:30	***Lunch***	
12:30 - 1:30	ISS and LEO Commercialization	Ms. Robyn Gatens
1:30 - 2:30	Space Life and Physical Sciences Research and Applications	Dr. Craig Kundrot
2:30 - 2:45	***Break***	
2:45-3:45	Commercial Space Division/Commercial Crew Program	Ms. Kathy Lueders
3:45-3:50	Public comments	
3:50- 4:00	***Break***	
4:00-5:30	Discussion and Recommendations	
5:30	***Adjourn***	

Wednesday March 29, 2017
NAC HEO COMMITTEE PUBLIC MEETING (CONTINUED)

8:00 – 8:05	Opening remarks.	Dr. Bette Siegel/Mr. Ken Bowersox
8:05-9:05	Exploration Systems Division	Mr. Bill Hill
9:05-10:05	Cislunar Hab/Environmental Control Life Support System	Mr. Jason Crusan/Ms. Robyn Gatens
10:05-10:20	***Break***	
10:20-11:20	In-space Power/Propulsion	Dr. Michele Gates
11:20 -12:00	Summary	Mr. Bill Gerstenmaier
12:00– 1:00	***Lunch***	
1:00-2:30	Discussion and Recommendations	
2:30	***Adjourn***	

Human Exploration and Operations Committee Membership
March 2017

Mr. Ken Bowersox, *Chair*

Dr. Bette Siegel *Executive Secretary*	NASA Headquarters
Mr. Ken Bowersox	Former NASA astronaut and retired U.S. Navy Captain
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
Washington, DC

March 28-29, 2017

MEETING ATTENDEES

HEO Committee Members:

Bowersox, Kenneth, *Chair*	Aerospace Consultant
Siegel, Bette, *Executive Secretary*	NASA Headquarters
Bartell, Shannon	Aerospace Consultant
Budden, Nancy Ann	Department of Defense
Chiao, Leroy	Aerospace Consultant
Condon, Stephen "Pat"	Aerospace Consultant
Gardner, Ruth	Kennedy Space Center
Hale, Wayne	Aerospace Consultant
Holloway, Tommy	Aerospace Consultant
Levin, Lon	SkySeven Ventures
Longnecker, David	Association of American Medical Colleges
Lopez-Alegria, Michael	Commercial Spaceflight Federation
Sieck, Robert	Aerospace Consultnat
Smith, Gerald	Aerospace Consultant

NASA Attendees:

Adde, Barbara
Archer, Ryan
Bessoir, James
Boggs, Kathleen
Clay, Bob
Crable, Vicki
Craig, Douglas
Crusan, Jason
Edwards, Ashley K.
Gafka, George
Gatens, Robyn
Gates, Michele
Gerstenmaier, William
Herrmann, Nicole
Hill, Bill
Hurst, Kim
Johnson, Patrick
Joshi, Jitendra
Kezel, Jonathan

Other Attendees:

Bingham, Jeff	Focused Solutions, LLC
Fanaco, Carlos	AAAS
Frankel, David	P B Frankel, LLC
Gump, David	Deep Space Industries
Karanian, Linda	Aerojet Rocketdyne
Li, Allen	HSST
Risen, Tom	Aerospace America
Sanders, Patricia	ASAP
Spry, J. Andy	SETI

Levin, Lon
McElroy, Chris
McElroy, Shana
McKay, Meredith
Miller, Jay
Murdoch, Jonathan
Newmann, Steve
Norman, Jim
Petro, Andrew
Pullen, Renee
Skrobot, Garrett
Smith, Marshall
Spivey, Jimry
Ticker, Ron
Whitmeyer, Tom
Williams, Greg

Human Exploration and Operations Committee
NASA Headquarters
Washington, DC

March 28-29, 2017

LIST OF PRESENTATION MATERIAL

1) Progress in Defining the Deep Space Gateway and Transport Plan [Gerstenmaier]
2) Architecture Status [Free]
3) International Space Station Status [Gatens]
4) Space Life and Physical Sciences Research and Applications [Kundrot]
5) Commercial Crew Program Status [Lueders]
6) Deep Space Exploration Systems [Hill]
7) Cislunar Habitation & Environmental Control & Life Support Systems [Crusan]
8) In-Space Power and Propulsion [Gates]
9) Spinoff 2017
10) S.442 An Act to authorize the programs of the National Aeronautics and Space Administration, and for other purposes