National Aeronautics and Space Administration
Washington, DC

NASA ADVISORY COUNCIL

Human Exploration and Operations Committee

July 25-26, 2016

Ohio Aerospace Institute
Cleveland, Ohio

MEETING MINUTES

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N. Wayne Hale, Interim Chair

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Bette Siegel, Executive Secretary

NASA Advisory Council
Human Exploration and Operations Committee
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MEETING MINUTES
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NASA Advisory Council
Human Exploration and Operations Committee
Meeting
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Monday, July 25

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. 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. Ken Bowersox. Mr. Bowersox acknowledged the presence of Dr. Patricia Sanders, a member of the NASA Aerospace Safety Advisory Panel (ASAP), who would be succeeding VADM Joseph Dyer as the Panel's chair. Mr. Bowersox noted that Mr. Jim Odom had retired from the Committee and that Committee member Mr. Richard Malow had passed away. Mr. Bowersox introduced new Committee members Ms. Ruth Gardner, who would be attending the meeting telephonically, and Mr. Gerald Smith. At Mr. Bowersox's request, the new members described their backgrounds.

Mr. Bowersox announced that the NASA Administrator, Mr. Charles Bolden, had asked him to serve as the Interim Chair for the NAC, replacing Dr. Steven Squyres, who has retired. Mr. Bowersox explained that he would, therefore, no longer serve as Committee chair, and he introduced Mr. Wayne Hale, who would immediately begin serving as the HEO Committee Interim Chair.

Mr. Hale welcomed everyone to the meeting. He noted that he engages in aerospace consulting work and would exercise care to recuse himself when appropriate in order to avoid the appearance of any conflict of interest. In that event, Ms. Nancy Ann Budden would chair the meeting. Mr. Hale reported that the NAC had expressed an interest in additional interaction with the ASAP and that he had recently attended an ASAP meeting.

Status of Human Exploration and Operations Mission Directorate

Mr. Hale introduced Mr. Bill Gerstenmaier, Associate Administrator (AA), Human Exploration and Operations Missions Directorate (HEOMD), who briefed the Committee on the status of the Directorate. Mr. Gerstenmaier presented a graphic for the Journey to Mars and explained that the most important elements on the graphic are the segments referred to as Earth Reliant, Proving Ground, and Earth Independent. He explained that going to Mars is "hard" and, to demonstrate

that, presented a chart showing that 25 of 44 robotic missions to Mars had been mission failures. Human exploration of Mars would be difficult for several reasons. The reentry speed on the return to Earth would be 13.5 kilometers per second (km/s). The astronauts would be away from Earth for 800 to 1,100 days in microgravity and exposed to high levels of radiation. Mars has a thin atmosphere and dusty conditions for surface operations. There is a 44-minute delay for 2-way communications, and every 26 months there is a 2-week blackout when Earth and Mars are on opposite sides of the sun. One hundred thirty tons of mass would be needed for the mission, meaning multiple launches per mission. Twenty tons of oxygen would be needed for ascent from the Mars surface.

Mr. Gerstenmaier reviewed a chart showing the human space exploration phases from the International Space Station (ISS or Station) to the surface of Mars. The current phase, Phase 0, is for testing exploration systems on the ISS. That phase ends when testing, research, and demonstrations are complete. He noted that two new phases—Phase 4a, "Development and Robotic Preparatory Missions" and Phase 4b, "Mars Human Landing Missions"—were recently added to the chart.

Mr. Gerstenmaier reviewed a chart showing where hardware for U.S. human space flight is being developed. He described the ISS Research and Development Conference held in July 2016 in San Diego, California. He described the Twins Study and recommended that people view the Omics video series about changes in the genome from spending time in space. The video can be found at http://www.nasa.gov/twins-study and http://www.nasa.cov/content/exploring-space-through-you-omics.

Mr. Gerstenmaier explained that NASA is investigating options and approaches to expedite commercial activity in Low Earth orbit (LEO). NASA is interested in increasing private sector demand for space research and expanding the work of the Center for the Advancement of Science in Space (CASIS), which manages the ISS National Laboratory. He reviewed a chart showing Commercial Resupply Services (CRS)-1 flights flown to date and planned future flights. He noted that CRS-2 contracts have been awarded to Orbital-ATK, Inc. (Orbital or OA), Sierra Nevada Corporation (SNC), and Space Exploration Technologies Corporation (SpaceX). A minimum of six missions will be ordered from each provider and are planned for launch beginning in 2019.

Mr. Gerstenmaier reviewed the progress over the previous quarter in the Commercial Crew Program (CCP). Boeing and SpaceX continue to advance their design concepts. Eight CCP missions are now in process, consisting of two test flights per partner and two post-certification missions per partner. An unfunded Space Act Agreement (SAA) has been entered into with Blue Origin for orbital human space transportation development. He reviewed a chart showing CCP major milestones.

Mr. Gerstenmaier reviewed the status of the Tracking and Data Relay Satellite-M (TDRS-M), the Space Network (SN) Ground Segment Sustainment (SGS S), and the Deep Space Network (DSN). He described the status of the Asteroid Retrieval Mission (ARM). The ARM allows NASA to gain experience in operations and activities for the Journey to Mars. He discussed the need to test habitation systems on the ISS. He explained that these are an integrated array of complex systems and components that include environmental control and life support systems (ECLSS), docking

capability, logistics management, radiation mitigation and monitoring, fire safety technologies, and crew health capabilities.

Mr. Gerstenmaier presented a short video showing the Bigelow Expandable Activity Module (BEAM) expansion cycle on the ISS. He discussed the Next Space Technologies for Exploration Partnerships (NextSTEP) schedule for developing a cislunar habitation module. He noted that there had been an overabundance of audits by the General Accounting Office (GAO) and the NASA Inspector General (IG). A chart listing those assignments was presented. He reviewed Ground Systems Development and Operations (GSDO) accomplishments. Mr. Gerstenmaier concluded his presentation by describing the HEO Mars planetarium outreach program.

Mr. Hale thanked Mr. Gerstenmaier for his presentation.

Status of Exploration Systems Development (ESD)

Mr. Hale introduced Mr. Bill Hill, ESD Program Director at NASA Headquarters, who briefed the Committee on ESD status. Mr. Hill reviewed a chart on ESD milestones. He discussed ESD's Exploration Mission (EM)-1 Integrated Mission Milestone Summary. The critical path for the mission remains the European Service Module (ESM). The Crew Module Adapter (CMA) is on the secondary critical path. He explained that the Service Module (SM) comprises two elements: the ESM and the CMA.

Mr. Hill reviewed a chart on ESD's top concerns. The largest concerns are integrated avionics and software verification and validation (V&V). Another major concern is the budget. He presented a chart on IG and GAO audits where ESD programs were a major focus. He explained that audits are overwhelming the small staff available to work on them.

Mr. Hill described the status of the Orion EM-1 Crew Module (CM) being assembled at the NASA Kennedy Space Center (KSC). The pressure vessel was shipped to KSC in February 2016. Initial power-on is scheduled for January 2017. The ESM Structural Test Article (STA) has been delivered to NASA's Plum Brook Station for acoustic and vibration testing. He explained that the Avionics Module had to be developed by NASA and could not be assigned to an international partner due to International Traffic in Arms Regulations (ITAR) requirements. The ESM and CMA EM-1 flight articles are scheduled to be mated into the EM-1 SM in Spring 2017. Mr. Hill reviewed Space Launch System (SLS) and GSDO recent performance. SLS Design Certification Review (DCR) is expected in January 2018.

Mr. Smith asked whether a vertical hold-down with explosive bolts similar to that used on the Space Shuttle would be used for SLS. Mr. Hill responded that a vertical hold-down would probably not be used on the SLS. Mr. Tommy Holloway asked whether that might present a problem in the event of an asymmetrical shutdown of engines. Mr. Hill responded that should not be an issue and that the physical weight of the vehicle would serve as the hold-down. In response to a question from Mr. Hale, Mr. Hill confirmed that engineering studies showed sufficient margins to support not using a vertical hold-down. Mr. Hale expressed concern if the SLS engines were to be fired briefly and the vehicle had to be moved.

Mr. Hill reviewed Cross-Program Systems Integration (CSI) accomplishments. He discussed cross program interdependencies and described how the Cross-Program Integration Team (CPIT) manages

those interdependencies, working with ESD and program schedulers, to ensure program needs are being met. He noted that 817 interdependencies have been identified by the team, with 267 currently active. He discussed the CPIT's top technical issues and emerging CPIT issues and concerns. He reviewed the major ESD CSI independent assessments in progress.

Mr. Hale requested a complete acronym list. Ms. Gardner requested the EM-2 vehicle configuration.

Mr. Hale thanked Mr. Hill for his presentation.

Status of International Space Station

Mr. Hale introduced Mr. Sam Scimemi, Director for ISS, HEOMD, who briefed the Committee on the status of the ISS. Mr. Scimemi reviewed the ISS Flight Plan and the upcoming launch schedule. Mr. Hale requested that the schedule be expanded to include launches planned in 2018. Mr. Scimemi described the crew for Increment 48. He described the major stage objectives for Increment 48 and the Increment 48 Extravehicular Activity (EVA) plan. In response to a question from Mr. Michael Lopez-Alegria, Mr. Gerstenmaier explained that robotics has helped to reduce the number of EVAs. Mr. Scimemi reviewed a chart on crew utilization time and discussed ISS research statistics. He presented a chart showing the Increment 47-48 Research Plan and Investigation List. He described the Biomolecule Sequencer investigation, which seeks to demonstrate that DNA sequencing is feasible in an orbiting spacecraft. He described the Phase Change Heat Exchanger project. He discussed the history of protein crystal growth on the ISS.

Mr. Scimemi presented a chart showing the status of consumables on the ISS. He discussed ISS vehicle issues. On June 9, 2016, the ISS experienced an unexpected torque due to inadvertent firing of Soyuz thrusters. On June 1, 2016, there was an inadvertent Progress thruster firing after soft dock had been achieved. A Russian commission determined that the vehicle software had not been configured correctly and, as a result, the vehicle thought it was still free-flying. On January 15, 2016, EVA 35 was terminated due to water in the helmet. The cause of the failure is still under investigation. In response to a question from Mr. Lopez-Alegria, Mr. Scimemi explained that NASA has not conducted any EVAs since January 2016, and is in an EVA emergency-use-only status.

Mr. Scimemi described the OA-6 mission success and discussed the OA-5 mission status. The Antares Stage Test was completed on May 31, 2016, and a Flight Readiness Review (FRR) is scheduled for August 11, 2016. He described the SpaceX-8 mission success and discussed the SpaceX-9 mission status. He reviewed the H-II Transfer Vehicle-6 (HTV-6) resupply spacecraft mission status.

Mr. Scimemi discussed the CRS-2 contract. The awardees are Orbital, SNC, and SpaceX. A minimum of six missions will be ordered from each provider. The missions are planned for launch in 2019. He reviewed a chart on the ISS Integration Status of Crew Vehicles.

Mr. Scimemi described the ISS Research and Development Conference held July 12-14, 2016, in San Diego, California. Ms. Nancy Ann Budden requested the dates for the next conference. Mr. Scimemi discussed a Request for Information (RFI) that has been issued to advance economic development in LEO through commercial use of the unique capabilities of the ISS. He noted that NASA is interested in technical solutions to advance those goals and is also interested in contract structures that would

advance private sector demand for LEO research. Mr. Scimemi concluded his presentation with a description of the successful deployment of the BEAM habitation module. He explained that the only advanced analysis conducted for that deployment was to ensure that there would be no harm to the ISS. In response to questions from Mr. Smith, Mr. Scimemi noted that the deployment took longer than expected and that the module's fabric provides its thermal stability. In response to a question from Ms. Budden, Mr. Scimemi explained that the BEAM habitation module does not have an airlock. In response to a question from Mr. Hale, Mr. Gerstenmaier explained that the probability of micro-meteoroid and orbital debris (MMOD) penetration is very, very low.

Mr. Hale thanked Mr. Scimemi for his presentation.

International Space Station Research Subcommittee Update

Mr. Hale introduced Dr. David Longnecker, who briefed the Committee on the status of the Research Subcommittee. Dr. Longnecker noted that Dr. Brad Carpenter, NASA Chief Scientist for the Space Life and Physical Sciences (SLPS) Division is a great partner and the Executive Secretary for the Research Sub-Committee. Dr. Longnecker explained that the Terms of Reference for the Research Subcommittee provide that it is established to review and assess NASA's approach to research in support of human exploration. The Research Subcommittee supports the HEO Committee through (i) advice and recommendations on the overall objectives, approach, content, and structure of research activities in HEOMD; and (ii) assessments on the effectiveness of relationships between HEOMD's missions and stakeholders in the research and educational sectors.

Dr. Longnecker described the Research Subcommittee members and reviewed the most recent Research Subcommittee agendas. He discussed examples of human health challenges, both in-flight and post-flight, for Exploration missions. He noted that potential issues for future meetings of the Research Subcommittee are: evaluating animal models that could address questions of human health and performance in extended partial gravity, identifying the activities that require human presence in the cislunar environment prior to a Mars mission, and ascertaining whether the portfolio of the SLPS Program is appropriately balanced. In response to a question from Mr. Lopez-Alegria, Dr. Carpenter explained that using small rodents as animal models for long-duration partial gravity such as the Mars mission may be of limited value, because the lifespan of a mouse or rat does not match timespan of a 1000-day mission.

Dr. Longnecker introduced Mr. Angel Otero, SLPS Research and Applications Division (SLPSRAD) Deputy Director. Mr. Otero explained how SLPSRAD aligns with the NASA Strategic Plan. He described SLPSRAD's research and application focus areas in space biology, human research, and physical sciences. He presented the SLPSRAD organization chart.

Mr. Otero described the Human Research Program (HRP). Its mission is to enable space exploration beyond LEO by reducing the risks to human health and performance through a focused program of basic, applied, and operational research. The HRP consists of the Space Radiation Element, Human Health Countermeasures Element, Exploration Medical Capabilities Element, Behavioral Health and Performance Element, Space Human Factors and Habitability Element, ISS Medical Projects Element, and the National Space Biomedical Research Institute (NSBRI). Mr. Otero discussed the risk-based human health framework. The intent is to enable successful space exploration by mitigating the risks of

spaceflight. He reviewed a chart on the integrated path to risk reduction. Mr. Gerstenmaier noted that the allowable percentage of carbon dioxide (CO_2) may need to be reduced and would require rethinking on environmental life support.

Mr. Otero presented an overview of HRP research plans by platform. He discussed the distinction between strategy and logistics. Quoting Omar Bradley, Mr. Otero stated that "amateurs talk strategy, professionals talk logistics." Mr. Otero noted that a serious obstacle to the research strategy is the limited crew time available for NASA-sponsored basic research on the ISS.

Mr. Otero described "Open Science." It is a shift from the traditional approach of enabling science for one specific Principal Investigator (PI) at a time, and it enhances science returns by having multiple investigators participate in flight experiments. He described the GeneLab Strategic Plan. He explained that SLPSRAD, to address recommendations from the National Research Council (NRC) 2011 Decadal Survey, has initiated a transition in the GeneLab Platform to the Open Science architecture to increase research opportunities. He reviewed the project goals for GeneLab and presented a chart showing its phased implementation.

Mr. Otero described the MaterialsLab, which will enable a new generation of materials science experiments on the ISS. The MaterialsLab goal is to seek higher-performing materials by understanding materials behavior in microgravity. He discussed a Memorandum of Understanding (MOU) between NASA and the National Institute of Standards and Technology (NIST) for a cooperative endeavor to support the MaterialsLab and facilitate collaboration with the NIST Material Measurement Laboratory (MML). The goal is to enable the transfer and commercialization of Federally-developed, materials-related research and technology in order to promote U.S. innovation and industrial competitiveness.

Mr. Otero described the ISS One-Year Mission, in which Astronaut Scott Kelly set the record for the longest duration American space mission at 340 days. Mr. Otero reviewed the mission's research objectives. In response to a question from Dr. Pat Condon, Mr. Scimemi explained that data from the mission is still being collected and would require at least another year to be completed. Mr. Gerstenmaier noted that it would take a few years to obtain results from the One-Year Mission. Mr. Otero described the Twins Study, which began to examine next generation genomics solutions to mitigating crew health and performance risks. He discussed the Observation and Analysis of Smectic Islands in Space (OASIS) investigation, which studies the unique behavior of liquid crystals in microgravity. He described the Cold Atom Laboratory (CAL), which will help explore the quantum universe. He explained that the quest for ever-colder temperatures has been an important theme in physics for over 100 years, leading to profound insights into nature and myriad new technologies. Microgravity offers the possibility of dramatically reducing the forces needed to confine an ultra-cold sample of atoms. The CAL will give scientists access to an unexplored quantum realm in which temperatures can be orders-of-magnitude below that achievable on Earth. He described the experiments that will be conducted and noted that there are three Nobel Laureates on the CAL science team.

Mr. Hale thanked Mr. Otero and Dr. Longnecker for their presentations.

Status of Asteroid Redirect Mission

Mr. Hale introduced Mr. Ron Ticker, Deputy Program Director for ARM, who briefed the Committee on the ARM status. There are three segments to the ARM: identify a target asteroid using ground and space-based assets, acquire a boulder from a large asteroid and redirect the asteroid boulder to the lunar vicinity using solar electric propulsion (SEP), and launch crew from Earth in an Orion spacecraft on an SLS rocket to rendezvous with the ARM robotic vehicle and asteroid boulder, conduct two EVAs to explore the asteroid boulder and return samples to Earth. The ARM is expected to contribute to deep-space human exploration because it would demonstrate: (i) advanced autonomous proximity operations in deep space with a natural body, (ii) high-powered SEP to transport multi-ton masses in space, (iii) integrated crew and robotic vehicle operations in deep space, and (iv) astronaut EVAs in deep space. The ARM would be an early mission in the Proving Ground of cislunar space.

Mr. Ticker reviewed a chart showing ARM progress. He described ARM upcoming events. He discussed the Asteroid Redirect Robotic Mission (ARRM) Formulation Guidance. The target launch date for the ARRM has been moved back one year. The Asteroid Redirect Crewed Mission (ARCM) has been moved to 2026. Dr. Condon expressed concern over the schedule urgency for the ARM in order to enable a Mars launch in the mid-2030s. Mr. Smith asked what items are most likely to delay the ARM. Mr. Ticker responded that any delays most likely would be attributable to the robotic system and the capture module. Mr. Gerstenmaier added that difficulty obtaining the necessary funding has caused a one-year slip in the schedule. In response to a question from Mr. Lopez-Alegria, Mr. Scimemi explained that NASA did not yet have a new suit strategy. Mr. Gerstenmaier noted that also is a funding issue. He explained that NASA has been receiving external direction on how to prioritize funding; for example, developing a habitation module was given priority over developing a new suit. He expressed concern about getting conflicting direction from authorizers, appropriators, the Administration, and Congress. In response to a question from Mr. Leroy Chiao, Mr. Gerstenmaier explained that the ARM would be conducted without developing a new airlock. Mr. Ticker reviewed a chart on the ARM alignment strategy. He presented a chart showing the Human Space Exploration Proving Ground Phases from Phase 0 ISS to the human Mars missions with ARM representing the culmination of Phase 1.

Mr. Ticker reviewed the eight strategic principles for sustainable exploration. He discussed the status of ARRM electric propulsion. He presented graphics showing capture module prototyping and testing at NASA Goddard Space Flight Center (GSFC), NASA Langley Research Center (LaRC), and at NASA's Jet Propulsion Laboratory (JPL).

Mr. Ticker explained that the ARRM acquisition strategy leverages existing commercially available U.S. industry capabilities for a high-power, SEP-based spacecraft. NASA has designated JPL as the lead NASA Center for the ARM. JPL will use a two-step acquisition process. The first step awarded study contracts that are underway with Lockheed Martin Space Systems, Boeing Phantom Works, Orbital, and Loral Space Systems. The second step will be competition for development and implementation of the flight spacecraft bus by one of the study participants. He noted that the Formulation and Support Team (FAST) identified ARM as a unique opportunity to gain a wide range of valuable knowledge beyond other asteroid missions and beyond what is available in current meteorite collections. FAST was a two-month effort that NASA chartered to help answer ARRM project questions during mission requirements development. The final FAST report can be found at: https://www.nasa.gov/feature/arm-fast.

Mr. Ticker discussed the ARRM planetary defense demonstration. It will employ an enhanced gravity tractor (EGT) using the collected boulder to augment the spacecraft's mass in order to increase the gravitational attraction. He explained that an actual EGT planetary defense mission would collect much more mass, increasing the technique's effectiveness. He described the current ARM reference target, asteroid 2008 EV_5. It is a large, hazardous-size asteroid and provides a representative target for a planetary defense demonstration. He explained that multiple tons of material would be collected by the ARRM and delivered to a stable lunar orbit, where easy access by asteroid mining companies and NASA partners would be enabled. Approximately 100 kilograms (kg) of material would be returned to Earth by astronauts during the crewed segment.

Mr. Ticker discussed the science of ARM samples. Obtaining deep-core samples would allow the pristine nature of asteroid volatiles to be investigated. He presented a recently released draft finding by the Small Bodies Assessment Group (SBAG). It states:

"SBAG supports and appreciates the continued engagement of the small bodies community by the Asteroid Redirect Mission (ARM), through mechanisms such as the recent Formulation Assessment and Support Team (FAST). SBAG supports the plan as presented by the ARM team to create opportunities for hosted payloads on the ARM spacecraft and to have a competitively selected Investigation Team, both of which would maximize the science return of the mission."

Mr. Ticker discussed the opportunity for participation on the ARM Investigation Team (IT). The IT is a multidisciplinary group of U.S. industry, academia, and government and international members. The IT assists in defining and supporting ARRM and ARCM investigations in science, planetary defense, in-situ resource utilization, and capability and technology demonstrations. NASA plans to issue a call for partner-provided payloads to fly on the ARRM. The call will be open to U.S. industry, academia, government agencies, NASA Centers, and international participation. Mr. Ticker reviewed a chart on preliminary ARRM prioritization for hosted payloads based on inputs from the FAST. He indicated that payloads that can perform multiple investigations and reduce risk for the ARRM would be preferred over other payloads. Mr. Ticker noted that the ARM mission formulation spans NASA centers across the U.S.

Mr. Hale noted that the current NAC recommendation on the ARM endorsed only the SEP segment; however, in light of Mr. Ticker's presentation, Mr. Hale believes that there is now significant scientific interest in the ARM that could serve as the basis for the Committee to suggest a revised recommendation to the NAC. He thanked Mr. Ticker for his presentation.

Wrap up and Discussion

Mr. Hale opened the floor to the Committee members for discussion and suggestions for findings and recommendations. Mr. Hale noted that Mr. Bowersox had requested that the Committee update the Observations and Top Concerns list from its last meeting. Dr. Condon commented that nothing had changed and suggested giving recognition to the progress that had been made by Mr. Gerstenmaier. Mr. Holloway remarked that the details for missions planned to take place 20 years from now don't matter; what matters are the details for the next 10 years. Mr. Gerstenmaier agreed. Mr. Gerstenmaier added that NASA is on track for EM-1 and EM-2, that definition is needed for EM-3, 4, and 5, that it is time to

shift gears and start making hard decisions, and that the decisions would be made in parallel with the transition to a new Administration. Mr. Gerstenmaier counseled that knowing when to make a decision is as important as knowing what the decision should be.

Mr. Smith asked Mr. Gerstenmaier for suggestions on what the Committee could say that would help him. Dr. Sanders remarked that the Committee "is an advisory committee and should be giving advice." Mr. Hale noted that the Committee's findings and recommendations carry significant weight.

Adjournment

The Committee adjourned for the day at 4:30 p.m.

Tuesday, July 26

Call to Order, Welcome, and Opening Remarks

Dr. Siegel called the HEO Committee meeting to order at 8:00 a.m. and welcomed everyone back. She announced that it would be a public meeting and that minutes would be taken and posted with all presentations. She introduced Mr. Hale.

Mr. Hale acknowledged that some people had been having difficulty accessing the meeting remotely. He noted that WebEx is an older platform and may not be supported well by Windows 10. Dr. Siegel agreed to look into alternatives.

System Maturation Teams, ECLSS/Fire Safety

Mr. Hale introduced Ms. Robyn Gatens, Deputy Director, ISS Division. Ms. Gatens briefed the Committee on the status of the Systems Maturation Teams (SMTs) for ECLSS and for fire safety systems. She explained that the HEOMD AA established SMTs in 2013 to help implement a capability-driven approach for future missions. The Advanced Exploration Systems (AES) was tasked with leading a directorate-wide effort to develop system maturation roadmaps defining improvements required in space flight systems to support the needs for future human space exploration. Those roadmaps would be used as a foundation for HEOMD input to the Chief Technologist's technology development roadmap updates. Multi-Center SMTs were established to guide the capability definition by developing roadmaps to define the activities required to advance critical capabilities, the means of demonstrating system performance, and the implementation planning to achieve the steps of the roadmap. The SMTs would also serve as ongoing subject matter expert teams. Ms. Gatens presented the SMT organization chart. She explained that there are fourteen SMTs, including one for fire safety and one for ECLSS and environmental monitoring (ECLSS-EM). The SMTs have no budget of their own but work with funding organizations to advocate for funding for gap-closing activities.

Ms. Gatens discussed the status of ECLSS-EM. She presented a chart showing the preliminary top-level objectives for Phases 0, 1, and 2 of the Human Space Exploration Phases from ISS to the Surface of

Mars. Phase 0 covers exploration research and systems testing on ISS. Phase 1 covers initial cislunar flight testing of exploration systems. Phase 2 covers cislunar validation of exploration capability. She discussed specific habitation systems objectives. She described Phase 0 habitation-systems testing on the ISS.

Ms. Gatens explained that developing ECLSS for Mars would be hard due to the lack of resupply, on-orbit monitoring, emergency crew return, and trash disposal. She discussed current ISS capabilities and challenges for atmosphere management, water management, waste management, and environmental monitoring. She presented a chart on ECLSS-EM capability gaps. The most critical gaps are CO_2 removal, oxygen recovery from CO_2, urine brine processing, reliable water and urine processing, on-orbit environmental monitoring, and metabolic solid waste collection. Ms. Gatens presented the overall Exploration ECLSS Roadmap. She described progress being made in atmosphere management, water management, waste management, and environmental monitoring.

Ms. Gatens discussed fire safety. She reviewed fire safety capability gaps. The most critical gaps are fire suppression, an emergency crew mask, combustion product monitoring, identifying material flammability limits in low-gravity environments, and post-fire cleanup and smoke removal. She presented the Exploration Fire Safety Roadmap. She described progress being made on the emergency crew mask, post-fire clean-up, a smoke-eater system, fire suppression, and combustion product monitoring.

Ms. Gatens described the Spacecraft Fire Experiment (Saffire), which is a series of experiments on multiple expendable flight vehicles. Saffire will involve much larger flames than previous experiments and will investigate the way fire spreads on a variety of combustible materials. The experiments will be conducted away from the ISS. Each Saffire experiment will be remotely operated and take place inside a three- by five-foot module, split into two compartments. One side of the module is an avionics bay that contains sensors, high-definition video cameras, and signal-processing equipment. The other side contains the hardware required to ignite a large flame and burn the fabrics and materials inside. Saffire I, II, and III are intended to address material flammability gaps. Saffire IV, V, and VI are intended to address detection, monitoring, and clean-up demonstrations.

Mr. Holloway expressed an interest in having the Committee receive presentations from all the SMTs.

Mr. Hale thanked Ms. Gatens for her presentation.

Habitation Module Talk

Mr. Hale introduced Mr. Jason Crusan, Director, HEOMD Advanced Exploration Systems (AES) Division, who participated telephonically. Mr. Crusan reviewed the reasons that cause human exploration of Mars to be hard. The crew would be away from Earth in microgravity and exposed to radiation for 800 to 1,100 days. The crew would be exposed to dust toxicity during surface operations. There would be a 44-minute 2-way communication time delay. Multiple 130-ton, heavy-lift launches would be required for each mission. The Earth re-entry speed would be 11.2 km/s. Twenty tons of oxygen would have to be produced in-situ on Mars for ascent to orbit.

Mr. Crusan reviewed a chart on the habitation development challenge. He explained that NASA's deep-space habitat development strategy is to develop a long-duration, deep-space habitat while at the same time stimulating the development of commercial habitats for LEO. To ensure NASA gains innovative habitation concepts from industry, NASA is using the Broad Agency Announcement (BAA) contracting mechanism to implement a phased approach for deep-space habitat development. AES has issued the NextSTEP 2 BAA, which is a follow-on to the NextSTEP BAA released in 2014. The NextSTEP 2 BAA requests industry proposals for concept studies and technology development projects in the areas of habitation, advanced propulsion, and small satellites. NextSTEP 2 also serves as an on-ramp for additional providers. He presented a chart on the deep-space habitation development strategy.

Mr. Crusan described the BEAM. It is an expandable habitat demonstration on the ISS and was installed on April 16, 2016. He presented a video showing the BEAM expansion cycle on the ISS and a photograph showing six astronauts inside the expanded module.

Mr. Crusan discussed NASA's approach to habitation capability development. He explained that the NextSTEP BAA Phase 1 habitation capability objectives are to develop innovative concepts and perform technology investigations. He described the type of missions that could be supported by the initial habitation capability. NASA has awarded Phase 1 contracts to Orbital, Boeing, Lockheed Martin, and Bigelow Aerospace. The contract deliverables include delineating the proposed scope for Phase 2 efforts. He presented a slide showing Phase 1 design concept studies from the four contractors.

Mr. Crusan reviewed several charts on the goals and objectives of NextSTEP BAA Habitation Capability Phase 2. One goal is to develop a deep space habitat with fully functional systems for ground-based testing by 2018. Another goal is to stimulate commercial habitats in LEO. A third goal is to develop capabilities for a deep-space transit habitat that could be flown on SLS flights beginning in the early- to mid-2020s. In response to a question from Mr. Holloway regarding the number of flights needed to demonstrate the system, Mr. Crusan explained that NASA wants to get to a Mars-capable system by the end of the Proving Ground. Mr. Scimemi added that fewer flights would be needed than were required for constructing the ISS. Mr. Crusan noted that the potential for obtaining different capabilities from domestic and international suppliers requires standards and common interfaces for aggregation. A NASA standards working group would be implemented during Phase 2. He described potential Government Furnished Equipment (GFE) to be reviewed during Phase 2 for ECLSS, modular power systems, avionics and software, docking hatches, and for radiation monitoring, modeling, and protection.

Mr. Crusan described ground habitat prototype integration testing for fidelity and functionality. The habitation prototypes would be used to support system integration, human factors and operations, and system functionality. He explained that the top level objective of testing is Phase 3 requirement refinement and risk reduction.

Mr. Hale asked whether artificial gravity was under consideration. Mr. Gerstenmaier responded that there are no studies showing that artificial gravity is needed from a health perspective. He added that artificial gravity would pose huge engineering problems. Dr. Longnecker advised that countermeasures other than partial gravity had to be found because when there is zero gravity, all

the blood that normally sits in the feet would settle in the head, and CO_2 dilates the cerebral blood vessels. Mr. Crusan presented a chart showing a notional Phase 2 schedule. He concluded his presentation with a discussion on the AES budget for habitation planning.

Mr. Hale thanked Mr. Crusan for his presentation.

Status of Commercial Crew Program

Mr. Hale introduced Mr. Phil McAlister, Director of Commercial Spaceflight Development, who presented via telephone and WebEx. Mr. McAlister explained that NASA's vision of commercial human space flight to LEO is a robust, vibrant enterprise with many providers and a wide range of private and public users. The CCP has two purposes. Its public purpose is to support the development of non-NASA markets for commercial human transportation services to and from LEO. Its NASA purpose is safe transport of NASA and NASA-sponsored astronauts to and from the ISS. Mr. Holloway suggested that a third purpose could be to institutionalize the best of the lessons learned. Mr. Gerstenmaier agreed that NASA should consider how lessons learned could be better documented. Mr. McAlister discussed the CCP highlights over the last quarter. There are eight CCP missions in process for SpaceX and Boeing. He presented a chart showing major milestones for NASA's commercial partners.

Mr. McAlister noted that NASA and Blue Origin have entered into a new, unfunded SAA. Its purpose is to facilitate the design and development of an orbital commercial human space transportation system. He explained that Blue Origin may eventually want to bid on providing crew transportation to the ISS; however, the SAA does not offer sufficient oversight for NASA to certify that system. Mr. McAlister noted that NASA has extended its SAA with SNC to June 2017 for development work on the Dream Chaser spacecraft.

Mr. McAlister reviewed a chart on CCP's programmatic risks. The top risks are requirements changes, the ability to close the loss of crew (LOC) gap, the search and rescue posture, and the ability to respond to ammonia leaks on the ISS that might propagate into the crew vehicle. In response to a question from Mr. Hale, Mr. McAlister stated that he does not expect any significant requirements changes. Mr. Hale cautioned that a requirements change after Critical Design Review (CDR) would have enormous consequences.

Mr. McAlister presented charts describing the Boeing and SpaceX architecture for their respective spacecraft, launch segment, and ground and operations segment. He reviewed recent Boeing and SpaceX accomplishments. He noted that SpaceX was developing its own suit in-house.

Mr. McAlister discussed the CCP budget. He noted that CCP would continue to manage crew transportation services to the ISS after partner vehicles are certified. He explained it is critical that CCP receive the full FY 2017 President's Budget Request in order to support planned milestones and end NASA's reliance on Russia for U.S. crew transportation to the ISS. NASA does not want to slow down its partners and stretch out the schedule due to funding issues. Dr. Condon observed that it is likely that there would be a Continuing Resolution (CR) in 2017. Mr. McAlister responded that a short-term CR would not be problematic.

Mr. Lon Levin asked whether insight and oversight in the CCP was adequately balanced. Mr. McAlister responded that the CCP struggles with that question all the time. The CCP strives to avoid being overly bureaucratic in order to allow the commercial partners to remain innovative. He stated that he is comfortable with the level of insight and oversight. He explained that requirements are not allowed in SAAs; however, NASA is now in a contractual posture that allows it to impose requirements because the Commercial Crew Transportation Capability (CCtCap) contracts are standard contracts under the Federal Acquisition Regulations (FAR). In response to a question from Mr. Lopez-Alegria, Mr. McAlister explained that a contract modification to the Soyuz contract added six more seats through spring of 2019, giving NASA additional flexibility; however, additional Soyuz seats may be needed.

Mr. Hale thanked Mr. McAlister for his presentation.

Public Comments

Mr. Hale invited comments from the public.

Mr. Steven Riley introduced himself telephonically. He observed that the NAC and NIST were not familiar with each other's studies, and he suggested that a catalogue be established of those studies, findings, and recommendations.

Mr. Hale thanked Mr. Riley for his comments. Mr. Hale noted that a public comment period would be available during the upcoming NAC meeting.

Committee Discussion, Findings & Recommendations

The Committee members reviewed the presentations that had been provided during the meeting. Mr. Hale reminded the Committee that Mr. Bowersox had requested an update to the Committee's list of top concerns. Dr. Siegel reminded the Committee that the NAC's process no longer includes observations. The Committee discussed whether it would be appropriate to recommend that the NAC participate in briefing the transition teams for the presidential candidates. Dr. Sanders suggested a finding that the number of IG and GAO reviews is adversely affecting the ability to execute programs.

Mr. Lopez-Alegria proposed a Committee finding to express concern over the ISS transportation gap for NASA crew and the potential need to procure additional Soyuz seats. After discussion, the Committee approved the following finding:

HEOC Finding Concerning Soyuz Transportation

- **Finding:** HEOC is concerned about the possibility of a gap in ISS transportation for NASA crew. The current schedules of both Commercial Crew Program (CCP) providers show completion of certification in time to allow for crew rotation to ISS in CY2018, however there is very little margin. Human spaceflight development programs invariably suffer schedule slips due to their technical complexity; the integration of commercial providers into government service adds further obstacles to CCP.

- It is therefore prudent to assume delays in post-certification missions from today's schedule. Since NASA has purchased Soyuz seats only through CY2018, any delay of CCP operational capability beyond CY2018 will result in the inability to send NASA astronauts to ISS until one of the CCP providers can complete certification.

Due to long lead time required to procure Soyuz seats, a decision must be made by the end of CY2016 to guarantee access to ISS in CY2019, or NASA may be forced to reduce

Ms. Budden proposed a Committee finding to express appreciation to Dr. Squyres and the NAC for their services. After discussion, the Committee approved the following finding:

HEOC Finding on Current NASA Status

- **Finding:** The HEOC commends the NASA Advisory Council and outgoing Chairman Dr. Stephen Squires for their commitment, leadership, and pertinent recommendations over the last several years. The deliberations of the NAC will continue to be essential for NASA as changes will likely follow the national elections in November 2016.
- The HEOC supports the current systematic approach to the ultimate goal of human exploration of Mars that is guided by the three domains of NASA's "Journey to Mars" strategy, which builds sequentially from Earth dependent to proving ground to Earth independent.
- We commend the leadership and staff of NASA HQ and the Centers for the steady progress being made on ISS, Commercial Crew, Orion, and SLS.

Mr. Holloway proposed a Committee recommendation for NASA to implement technology development as quickly as possible once a requirement for a technology has been sufficiently defined. After discussion, the Committee approved the following Finding.

HEOC Finding on Technology Development and Mars Architecture

- **FINDING:** The overall architecture for "Journey to Mars" has matured to the point that allows effective focus on the next steps to successfully meeting the goal of humans exploring Mars. A sound detailed architecture through the next ten years to allow adequate definition of technology development requirements.
- To ensure time and money are effectively utilized toward the "Journey to Mars" campaign:
  - Continue to review, identify, and refine the technology needs. Then the schedule should be developed for implementation in a timely manner.
  - Develop schedules and implementation of development of elements for Phases 1&2 of the campaign to ensure NASA R&D is positioned to efficiently accomplish Phases 3&4.
  - Determine the schedule of the technology development campaign.

Observations from the presentations:

- HEOMD has added detail to plans for human exploration missions in the 2020's to identify near term technology development requirements.

- ISS test bed for technology development for deep space exploration is critical and good definition has been made on identifying priorities and critical work to be accomplished during ISS operational lifetime.
- Continued progress is being made on Commercial Crew, SLS, and Orion with no major schedule adjustments due to technical or resource issues.
- ARM planning and development is continuing. The Formulation and Assessment Team's report has been very helpful. Engagement with the Small Body Assessment Group has improved science potential. Planetary defense objectives have been included.

Dr. Longnecker suggested that the HRP brief the Committee on progress that has been made on the remaining challenges. The Committee approved adding this item to the Committee's Future Special Topics. The Committee approved adding the adverse impact attributable to the number and intensity of external reviews to the Committee's Top Concerns.

The Committee continued to work on identifying a set of Top Concerns. The following Top Concerns, in no order of priority, were approved by consensus: HEOMD has added detail to plans for human exploration missions in the 2020's to identify near term technology development requirements.

- ISS test bed for technology development for deep space exploration is critical and good definition has been made on identifying priorities and critical work to be accomplished during ISS operational lifetime.
- Continued progress is being made on Commercial Crew, SLS, and Orion with no major schedule adjustments due to technical or resource issues.
- ARM planning and development is continuing. The Formulation and Assessment Team's report has been very helpful. Engagement with the Small Body Assessment Group has improved science potential. Planetary defense objectives have been included.

Special topics for future meetings:

- Briefing from the Human Research Program on progress and remaining challenges
- International Participation in Future Human Exploration
- Plans for Transition of Administration
- ISS Research
- ISS Component Reliability
- Lunar Distant Retrograde Orbit
- Briefings from Selected System Maturation Team Leads
- Integrated Testing Program/Schedule for "Journey to Mars"

Topics for continued review:

- NASA Management Processes
- Certification of readiness process for commercial crew
- ISS Uses for Exploration Development, Transition, and Exploration Plans Beyond ISS
- Commercial Involvement in Future Human Exploration

Dr. Siegel thanked the staff at NASA Glenn Research Center for their assistance in supporting the Committee's meeting. She also thanked Ms. Shawanda Robinson for her assistance.

Adjournment

The Committee meeting adjourned at 2:00 p.m.

NASA ADVISORY COUNCIL
Human Exploration and Operations Committee
MEETING
Ohio Aerospace Institute
22800 Cedar Point Road – President's Room
Cleveland, OH 44142

July 25-26, 2016

AGENDA

Monday, July 25

NAC HEO COMMITTEE PUBLIC MEETING

9:30 am	Call to Order, Welcome & Opening Remarks	NAC HEOC Chair & Dr. Bette Siegel
9:30 – 10:00	Status of Human Exploration & Operations Mission Directorate	Mr. Bill Gerstenmaier
10:30 – 11:30	Status of Exploration Systems Development	Mr. Bill Hill
11:30 – 12:30 pm	***LUNCH***	
12:30 – 1:30	Status of International Space Station	Mr. Sam Scimemi
1:30 – 2:30	International Space Station Research Research Subcommittee Update	Mr. Angel Otero Dr. David Longnecker
2:30 – 3:30	Status of Asteroid Redirect Mission	Dr. Michele Gates
3:45 – 4:30	Wrap up and Discussion	
4:30	***ADJOURN***	

Tuesday, July 26

NAC HEO COMMITTEE PUBLIC MEETING

8:00 – 8:05	Call to Order, Welcome & Opening Remarks	NAC HEOC Chair & Dr. Bette Siegel
8:05 – 9:00	System Maturation Teams ECLSS/Fire Safety	Ms. Robyn Gatens
9:00 – 10:00	Habitation Module Talk	Mr. Jason Crusan
10:00 – 10:15	***BREAK***	
10:15 – 11:15	Status of Commercial Crew Program	Mr. Phil McAlister
11:15 – 11:20	Public Comments	
11:20 – 12:00	Committee Discussion, Findings & Recommendations	
12:00 – 1:00	***LUNCH***	
1:00 – 2:00	Committee Discussion, Findings & Recommendations	
2:00	***ADJOURN***	

Human Exploration and Operations Committee Membership
July 2016

Mr. N. Wayne Hale *Interim Chair*	Consultant, Special Aerospace Services of Boulder, Colorado
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 Glenn Research Center
Cleveland, Ohio

July 25-26, 2016

MEETING ATTENDEES

HEO Committee Members:

Hale, Wayne, *Interim Chair*	Aerospace Consultant
Siegel, Bette, *Executive Secretary*	NASA Headquarters
Bowersox, Ken	U.S. Navy Captain (Ret.)
Budden, Nancy Anne	Office of the Secretary of Defense
Chiao, Leroy	Aerospace Consultant
Condon, Stephen "Pat"	Aerospace Consultant
Gardner, Ruth (via telecom)	Kennedy Space Center
Holloway, Tommy	Aerospace Consultant
Levin, Lon	SkySeven Ventures
Longnecker, David	Association of American Medical Colleges
Lopez-Alegria, Michael	Commercial Spaceflight Federation
Smith, Gerald	Aerospace Consultant

NASA Attendees:

Gatens, Robin	NASA HQ
Lilley, Steve	NASA Safety Center
Ticker, Ron	NASA HQ
Williams, Greg	NASA HQ
Carpenter, Brad	NASA HQ
Otero, Angel M.	NASA HQ
Robinson, Shawanda	NASA HQ

Other Attendees:

Johanson, Mike	Zin Technologies
Salzman, Jack	[private consultant]
Frankel, David	P B Frankel, LLC

Telecon Attendees:

Allen, Gale
Barber, Sara
Bog, Katie
Branscome, Darrell

Chappell, Laurie
Ching, Mike
Clark, Steven
Colangelo, Anthony
Cruzan, Jason
Dean, James
Dittmar, Mary Lynne
Eisenman, David
Faith, Ryan
Foust, Jeff
Gage, Douglas
Gallagher, Kathleen
Gates, Michelle
Gilbert, Chris
Guidi, John
Gump, David
Hanbleton, Kathryn
Hennig, Anthony
Holland, Lindsey
Irving, Richard
Jordan, Bill
Karanian, Linda
Kranz, Jean Marie
Kunstadter, Chris
Laurini, Kathy
Leck, Renee
Mahoney, Erin
Mahoney, Karen
Mark, Alex
Marquez, Peter
McAlister, Philip
McClean, John
McKauka, Jean
McKay, Meredith
McKinney, Richard
Messier, D.
Millman, David
Murray, Matt
Murrow, Dave
Oesterle, Aaron
Patel, Neel
Perrotto, Trent
Peters, Jennifer
Pitt, Sean
Putter, Phil
Ready, Irvin

Reilly, Deann
Riley, Andrea
Rummel, John
Ryan, Stephen
Schaefer, Ryan
Scheld, Dan
Singleton, Daniel
Sloss, Philip
Smith, Marcia
Smith, R.
Stirone, Shannon
Tabache, Micheline
Thomas, Daniel
Thompson, Tabatha
Urycki, Mark P.
Vander Galien, Craig
Van Wychen, Kristin
Witze, Alexandra

Human Exploration and Operations Committee
Ohio Aerospace Institute
Cleveland, Ohio

July 25-26, 2016

LIST OF PRESENTATION MATERIAL

1) Status of Human Exploration & Operations Mission Directorate [Gerstenmaier]
2) Exploration Systems Development Update [Hill]
3) International Space Station Status [Scimemi]
4) Research Subcommittee Report [Longnecker]
5) Space Life and Physical Sciences [Otero]
6) Asteroid Redirect Mission Update [Gates]
7) Environmental Control & Life Support/Fire Safety Systems Maturation Team Status [Gatens]
8) Habitation Module [Crusan]
9) Commercial Crew Program Status [McAlister]