National Aeronautics and Space Administration
Washington, DC

NASA ADVISORY COUNCIL
Human Exploration and Operations Committee

July 13, 2022
NASA Headquarters
Virtual Meeting

MEETING MINUTES

Bette Siegel, Executive Secretary	**N. Wayne Hale, Chair**

Public Meeting Minutes
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Meeting Report prepared by

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July 13, 2022

Call to Order/Announcements

Dr. Bette Siegel called the joint meeting of the Human Exploration and Operations Committee (HEOC) and Science Committee (SC) to order, and detailed the Federal Advisory Committee Act (FACA) rules that govern the NASA Advisory Council (NAC) Committees. She introduced the Chairs of the HEOC, Mr. N. Wayne Hale, and SC, Dr. Ellen Williams. Dr. Williams introduced herself and led introductions around the table. Mr. Hale introduced himself, spoke briefly and introduced comments from General Lester Lyles, Chair of the NASA Advisory Council.

Welcome and Introduction

General Lyles greeted meeting participants, and said he would be speaking to NASA Administrator, the Honorable William Nelson, in advance of the full NAC meeting schedule for early August.

Moon to Mars Architecture

Ms. Cathy Koerner presented details of NASA's Moon to Mars architecture, which is a rationale that has been informed by numerous bipartisan administrations and policy documents over the past several years; principally the White House U.S Space Priorities Framework of December 2021, which states that "The United States will maintain its leadership in space exploration and space science, and remain a global leader in science and engineering by pioneering space research and technology that propels exploration of the Moon, Mars, and beyond."

The focus of the Moon to Mars Architecture is, first and foremost, science in Exploration. Science connects all the elements of the "Why" of Exploration, enables the mission itself (e.g., via methods of in-situ resource utilization, or ISRU) and includes the incorporation of Decadal-Survey level science objectives. The goal is to have an annual cadence of launches to the Moon, while using analogs such as the International Space Station (ISS) and the lunar surface, and expanding partnerships, while NASA moves outward in the Solar System to Mars and beyond. Specific Moon to Mars objectives are categorized under four themes: Science, Transportation and Habitation, Lunar and Mars Infrastructure, and Operations. NASA recently hosted a US-based workshop in Houston, inviting 32 organizations or individuals to have one-on-one dialogues with subject matter experts (SMEs) and organizations across NASA. The UK Space Agency (UKSA) will be hosting a similar workshop in London during the third week of July, to identify parallel opportunities.

The Moon to Mars architecture in this context is defined as a set of functional capabilities which enable the implementation of various mission scenarios: transportation, habitation and life support, and infrastructure. With renewed emphasis on the Moon to Mars pathway, NASA reorganized the Human Exploration and Operations Directorate (HEOMD) into two different entities: the Exploration Systems Development Mission Directorate (ESDMD), and the Space Operations Mission Directorate (SOMD). The two directorates are coordinating with the Science Mission Directorate (SMD) in working with Decadal Survey objectives. The Agency is bringing in new international and commercial partners, and is refining lists for landing regions on the Moon. NASA Deputy Administrator, Colonel Pamela Melroy, has asked for a series of white papers explaining the decision process behind the architecture evolutions, and there will be an internal architecture concept review next year. NASA is also in the process of awarding a number of procurements. Moon to Mars architecture will progress through an iterative cycle, based on a strategy and budget that will take into account advanced capabilities and technologies as they develop.

The architecture builds on existing capabilities (low-Earth orbit assets, terrestrial analogs) through lunar return, to sustained lunar presence, to humans on Mars. NASA is preparing Artemis I for a late Summer or early Fall launch. The integrated Orion/Space Launch System (SLS) stack recently completed a wet dress rehearsal. The Artemis I mission will span a total of 26-42 days, maneuver in a distant retrograde orbit (DRO) around the Moon for 6-19 days, while flying a number of technology demonstrations and science experiments. Artemis II will be the first crewed test of the Orion spacecraft. Artemis II will test out a number of systems while flying to a high Earth orbit, and also perform proximity operations testing. The Artemis III mission will be the crewed mission to the lunar surface, and will include the ESA Service Module (ESM3) as did Artemis 1 and 2. Artemis III will also include a version of a Human Landing System (HLS); SpaceX has been selected to build Option A, which is called Starship. SpaceX has designed a few versions of Starship, and other companies are developing and demonstrating similar transport services.

NASA is in the process of upgrading space suits and related equipment in preparation for Artemis, as well as vehicle interfaces (VISE), tools and equipment; the Agency made a recent award in this area. The Gateway component of the Artemis program will function as a staging point for human and robotic exploration, a host for science experiments, and a testbed, and will launch between the Artemis II and III missions. Gateway will consist initially of a Power and Propulsion Element (PPE) and a Habitation and Logistics Outpost (HALO). The Canadian Space Agency (CSA) will provide a robotic arm, ESA a habitat (I-HAB) and the Japanese Aerospace Exploration Agency (JAXA) will provide an environmental control system. Early Gateway science payloads will include radiation sensors and space weather instrumentation. The Gateway integrated spacecraft will be supported by many international partners. As with the Apollo mission sample collection regime, the Artemis missions will increase sample collection as they increase in lunar surface capability.

Dr. Chavers addressed details of the Lunar Terrain Vehicle (LTV), for which requirements definition is now in work. The first LTV will be unpressurized; its purpose is to take crew far from the landing site. The LTV has a 10-year lifetime requirement, so that it is reusable. The current plan is for solar-powered, remote operations. The LTV is intended to have interfaces for science payloads, and it will also be designed to deliver instruments. Because the lunar south pole is heavily shadowed and there is limited sunlight available, the Agency is currently studying ways to survive the 150-hour eclipse periods. The LTV underwent a System Requirements Review in May 2022, and it will undergo a Key Decision Point-A (KDP-A) review at Headquarters within the next month or so. A Request for Proposal (RFP) announcement is scheduled for Fall 2022. After LTV, planning will move forward for developing a pressurized rover that can provide 30 days of habitation for two crew members, as well as volume for spares and logistics. The pressurized rover will also be reusable for up to 10 years, and feed forward for human missions to Mars. Surface habitation is envisioned as a primary asset for sustained lunar presence, and NASA working with industry to develop concepts and designs for a surface habitat that will accommodate 2 to 4 crew for a 30 to 60 day stay. It will be EVA-capable, with suit maintenance capability, and serve as a communication hub for surface assets; and reusable for up to 15 years.

NASA is exploring concepts for an Artemis ISRU pilot plant, to demonstrate a scalable capability to extract and use surface resources for lunar-based missions. Capabilities could include oxygen extraction, water mining, and refining materials for lunar surface construction. Another concept is the use of fission surface power, which is also identified as an enabling capability for Mars exploration, that will support longer sorties on the lunar surface. Studies are also under way for a transit habitat, another reusable element that will have a 15-year lifetime to enable multiple missions. The transit habitat has several feed forward uses for Mars, as it will be designed to keep crew healthy and productive during long-duration, deep-space stays including: shakedown missions at Gateway and while free-flying with interim propulsion; Lunar-Mars analogs; and up to 1100-day Mars transit and orbital stays.

Twenty countries have joined the NASA Artemis Accords, an agreement that represents nations united for the peaceful exploration of deep space. The terms of the Accords are grounded in the United Nations 1967 Outer Space Treaty. There are three current international partner architecture contributions to Artemis, in addition to study agreements and identification of potential areas for future discussion: power infrastructure and distribution; communication and navigation; logistics; and robotics and mobility, etc. **General Lyles, interjecting in a chat comment, suggested the Committees consult Karen Feldstein for an Artemis Accord summary.

Ground-based analogs are under way, such as DesertRATS-Lite in Arizona, in collaboration with JAXA, which will include testing of a pressurized rover. Other analogs include Arctic and volcanic environments. The Human Exploration Research Analog (HERA) at Johnson Space Center is conducting a series of 45-day missions designed to evaluate crew performance under isolation, confinement, and remote conditions in exploration scenarios. CHAPEA—Crew Health and Performance Exploration Analog—also at JSC, is an exercise aimed at Mars missions. The first conceptual Mars mission is also being studied. The mission assumes the ability to pre-deploy cargo and a crew ascent vehicle on 25-ton class Mars landers. A transit habitat and propulsion stage would support four crew on the long mission to Mars, allowing two crew to remain in orbit while two crew visit the Mars surface. The notional mission would allow for gradual acclimation out of microgravity to Mars gravity. Dr. Chavers impressed upon the audience that the complex Moon to Mars pathway would require a truly global endeavor.

Cross-Directorate Science Utilization

Dr. Jacob Bleacher, Chief Exploration Scientist in ESDMD, and acting manager for Science and Technology Utilization, gave the briefing. He described the Moon as a library that has recorded the history of processes that shaped the Solar System, and a site that holds the key to understanding Big Science questions including those related to volatiles. The Apollo program explored the equatorial near-side region of the Moon. Artemis is going to explore the South Pole of the Moon, which will address new objectives and enable entirely new observations. Artemis science objectives are to :Understand planetary processes, impact history of Earth-Moon system, etc. Currently, NASA is documenting community input through ongoing activities such as the Lunar Surface Science Workshop (LSSW). STMD is also interested in the Moon, and is working alongside ESDMD to understand what will be needed to meet lunar objectives; some technology objectives have strong cross-over to science, such as ISRU. Other cross-over areas include surface power, dust mitigation, etc. Research objectives common to both ESDMD and SOMD include space radiation, the effects of isolation and confinement on performance, issues associated with remote distance from Earth, gravity or lack thereof, and the effects of hostile/closed environments. Dr. Bleacher stressed that all of these objectives are based on decades of community input.

ESDMD/SOMD directorate level technical documentation, or the Utilization Plan (HEOMD-006), contains Science and Technology utilization goals, and is closely connected to HEOMD-004, which is the Requirements document. To help integrate across mission directorates, the Science and Technology and Utilization group provides documents in "Annexes" that serve as touchpoints to ensure traceability and flow of content. ESDMD has stood up a Utilization Coordination and Integration Working Group (UCIG) with SMD and STMD to maintain communication, and ESDMD also interfaces with SMD on their Commercial Lunar Procurement Services (CLPS) manifest selection board.

HEOMD-006 encompasses representation from SMD, SOMD, ESDMD and STMD. The document is released publicly to [[ntrs.nasa.gov]], to enable routine comment from the community. Community workshops will often trace into documents like this. ESDMD wants very much to understand what the community wants. Some examples of content in the Utilization plan, broken down by directorate, include high-level goals such as: Enable science investigations on the surface of Mars, in Mars orbit, and in Mars transit (SMD) and; Advance knowledge to support safe, productive human space travel, and enable systems development and testing to reduce health and performance risks for future human exploration

(ESDMD). Each directorate owns its utilization goals. Change reviews are done through the UCIG, ensuring that everyone knows when changes have occurred and that they have been recorded, thus enabling strong traceability. Dr. Bleacher provided an example of an "Annex" from the HEOMD-006 Utilization Plan, describing cornerstone capabilities that enable multiple objectives: model traverse approaches, end-to-end sample return (returning frozen samples, e.g. from permanently shadowed regions), integrated planetary protection strategies; and integrated crew research.

Artemis as a foundation for deep space exploration will require combined capabilities: SLS, Orion, HLS, Surface Operations, Gateway, EGS, SCaN, surface mobility, space suits, and an Artemis base camp. Landing humans on the Moon will rely on information that has been collected about the Moon by such assets as the Lunar Reconnaissance Orbiter, whose imagery is informing the human exploration architecture. Infusing science from beginning, Artemis I will enable a number of cubesats for science and technology investigations and demonstrations. Orion will carry internal payloads as well, to understand conditions in the interior of the capsule: radiation sensors, a voice-activated virtual assistant that enables hands-free crew interface, and battery-operated biological experiments. A draft Cooperative Agreement Notice (CAN) announcement is now in process for the Solar System Exploration Research Virtual Institute (SSERVI). SSERVI supports human exploration and scientific discovery by integrating interdisciplinary research to prioritize and resolve key knowledge gaps. SSERVI is co-funded by SMD and ESDMD, and holds its own exploration forum every year. This year's forum combines exploration aspects with the science.

Early Gateway science payloads include ERSA, an ESA-contributed radiation instrument package, NASA's HERMES space weather sensor suite, and an ESA/JAXA Internal Dosimeter Array. Eventually, an Artemis Base Camp on the Moon will be key to opening access to the lunar surface, to find the pieces of evidence to answer science questions. Each addition to the Base Camp componentry and Artemis campaign will increase time on surface and on orbit, to collect data for the next big steps out into the Solar System, as well as the time needed to perfect the human-robotic interaction needed to enable humans to survive and thrive in space.

Artemis Science Team Formation

Dr. Sarah Noble provided details about the new Artemis Science Team, which builds on the accumulated knowledge of the Apollo and Constellation programs. NASA has had 50 years to think about new science, using new technologies, and now has a better understanding of where we want to go and what we want to do. NASA is also larger; it has a large cadre of talented lunar scientists among its civil servants. The Artemis Science Team will eventually include assigned internal NASA scientists as well as those selected through competition. The Artemis I Science Team plan only covers the initial "sortie" phase of Artemis. The Artemis III Science Team will consist of an internal Artemis Science Team, a competitively selected Geology Team, and competitively selected payload teams. The roles of the internal team will be to ensure that the architecture and systems can support science; in addition, the internal team members will serve as interfaces between NASA and the competed teams to maximize science return, and participate in program-level strategic planning for mission to mission continuity. The competed Geology team roles will be focused on the Artemis III sortie, and will help to develop mission science objectives for that sortie. The Geology team will also consider field science goals, traverse planning, sampling strategy, support training as needed in real-time operations, support preliminary examination of samples, and provide a post-mission geology report.

The internal Artemis Science Team is now on board, with expertise on training and operations, sample collection planning and data, and payloads. The team is looking for a new Curation Lead, and a Contamination Control Lead. Astronauts are undergoing basic geology training under the aegis of Artemis planetary science training. There are also a number of analog activities at every level, as reported

in Dr. Chavers' presentations. NASA is now working on developing a curriculum for Artemis III. A select number of ROSES22 elements will also cover instrument aspects of lunar exploration.

Asked how instruments would be selected, Dr. Noble said that instruments would be discussed only after the selection. Questions will be posted publicly on a FAQ webpage. Dr. Cerf asked if the Artemis III Geology Team would include international members. Dr. Noble said the Principal Investigators must be U.S. citizens, but the PI can have international co-Investigators. The Participating Scientist Program (PSP), however, will be open to internationals. For payloads, there will be an open call for both U.S. and international participants, with the exception of Russian or Chinese citizens. Currently, the Artemis Science Team includes geology as the only science topic; the Internal Science Team will ensure that the needs of other science fields are incorporated. Dr. Noble said much thought is being given to transparency, and noted that the twenty selectees will have much community behind them. Data and samples will also be made public, ensuring that all those who are interested will have access. Besides geology, presumably payloads can eventually expand to Heliophysics or biological teams. One purpose of ESSIO is to integrate across SMD, and not just PSD, making sure all their objectives are recorded.

Dr. Noble reported that LSSW sessions, held once per month, are completely virtual at present, and there have been 18 sessions to date. LSSW has been a great way to stay in touch with the community. Once a year, NASA does an outbrief to the community to keep the community informed about the progress and challenges of Artemis. Each session is about a half-day, and it generates a summary report that can be found on the website. Asked if Google could post these reports, Dr. Noble welcomed the idea, and added that all workshop talks are recorded, and are also on the LSSW website [[https://lunarscience.arc.nasa.gov/lssw]]. Select findings of recent workshop sessions include commentary on sample collection and planetary protection. NASA has found that the LSSW virtual series has been successful in gathering community input across a variety of topics, and that workshop reports are being used across the Agency to provide science input into Artemis. More virtual LSSWs are being planned around a variety of high-priority topics.

Answering a question from a meeting participant on LSSW, Dr. Noble said there had been some regular international participation, and that many other topics continue to bubble up from the global community. Dr. Cerf asked if radiation effects on electronic equipment were being studied in the Artemis effort. Dr. Noble said that some SSERVI projects have been looking at the plasma environment, through modeling work, at Goddard Space Flight Center, providing a good example of how SSERVI bridges gaps. A meeting participant commented that Gateway is a prime example of helping NASA understand impacts on crew and hardware. Dr. Cerf asked how governance and policy issues were dealt with. Dr. Noble said that the 9th floor policy office at Headquarters deals with such issues, within the framework of the Artemis Accords. However, each country within the Artemis Accords act under their own agreements. As to individual or corporate efforts at the Moon, Dr. Siegel cited the Outer Space Treaty (OST) as essential guidance, but enforcement is another issue altogether. Some meeting participants pondered whether there was some language in the Accords parallel to Article VI in the OST. Mr. Marc Weiser asked if the LTV would provide a science platform while there are astronauts on the surface. Dr. Noble affirmed that this was the case. yes. Mr. Weiser said it would be interesting to understand the platform, if it were like ISS and payloads could be plugged in, or removed, providing re-usable interfaces. Dr. Bleacher said NASA would be putting out an RFP on the platform design, leaving it to industry to drive innovation on what the platform would look like. NASA held an Industry Day on the subject and is looking forward to creative solutions. There have been discussions about interoperability, re-use, etc., and the discussions are ongoing.

Integration and Implementation of Science in Artemis

Ms. Stephanie Dudley briefed details of how science activities would be integrated into operations during the Artemis campaign. Strong relationships throughout the directorates, and allocation of resources to the

users, are already under way. Science activities have been incorporated early on in both Artemis I and Gateway, through a common utilization interface that is making things as interoperable as possible throughout the campaign. Starting 4 or 5 years out, the campaign looks at crew, sites, the number of EVAs, etc. which inform the available resources for a mission. Working through the UCIG, priorities are determined across a mission and allocations get documented in one of the Annexes, each of which is approved at the quad-directorate board level. SMD then decides how to treat its available resources, and puts out the calls to compete a payload. During solicitations, conflicts are avoided by having the team available to answer questions during selection periods. It is helpful if the teams do not spend time and energy if the payload is not feasible, so it is necessary to determine questions about feasibility as quickly as possible, and make them publicly answerable. Once payloads are selected, the team goes to each payload and determines crew time, mass, and power requirements, which also gets documented in the Artemis utilization plans, including the prioritization of the research. Eventually each payload gets a payload integration manager, the key person that assists payload teams in developing their unique documentation. Utilization plans acquire more fidelity as time goes on, and then get turned over to the execution and planning team, between 2 years and 6 months before a mission.

Initial Gateway science payloads help to illustrate utilization interface definition examples, such as a version of an ISS "locker," also known as internal mounted payload banks. There will be some external attached payloads on Gateway as well. The goal would be to have similar interfaces for external lunar orbit payloads and another for external lunar surface elements. In summary, the Artemis Campaign is actively working to accommodate cutting edge science and technology utilization today:

- SMD and STMD utilization requirements are worked together with the Artemis Campaign at the NASA Directorate level
- Utilization begins on Artemis I!
- Gateway will launch with multiple science payloads
- Initial planning for Artemis III surface utilization has begun

Asked if there were any integration between Artemis and CLPS interfaces, Ms. Dudley said there are crew requirements for touchpoints (inside the Orion capsule) that are "beefier" in design, compared to ISS. At some levels the answer is yes, but it is not one-to-one. Ms. Dudley pointed out that NASA does have to work with what comes back in proposal calls.

<u>Discussion of the Planetary Decadal</u>

Dr. Noble summarized the Human Exploration chapter of the newly released Planetary Decadal Survey, providing some background on the Survey and what it means for NASA. The Decadal Survey trumps all other community-generated guidance. The third Planetary Decadal Survey is entitled *Origins, Worlds, Life (OWL)*. Each Decadal Survey is about a 3-year process, and uses mission studies, solicited white papers, and other community input to determine the top science questions and missions for the decade's pursuit. Planetary Defense and Human Exploration were included in the Planetary Decadal Survey for the first time. Dr. Noble briefly reviewed the Steering Group and topic panels. *OWL* focused on science questions rather than destinations/targets this time, although the subject panels were based on targets (small bodies, Moon and Mercury, e.g.)

There were 12 priority science questions in total, with the Moon having been very well integrated into the big questions about the Solar System. The crucial role of sample return, and the importance of primordial processes rank high in terms of lunar science. The chapter on Human Exploration regarded lunar exploration as both aspirational and inspirational, and discussed the reasoning behind using humans rather than robots for lunar science, such as the abilities of the discerning human brain, and the human's superior ability to deploy instruments. *OWL* defined three themes for lunar exploration: uncover the lunar record of the Solar System's origin and early history; understand the geologic processes that shaped early

Earth, which are best preserved on the Moon; and reveal the origins of inner Solar System volatiles, as well as the delivery processes. A number of Human Exploration recommendations are also in *OWL* chapters 19 and 22, including a very long traverse (1000 km) lunar mission, Endurance A, which fits in well with the Artemis campaign. Dr. Noble noted that the HEOMD-006 documentation does contain a section on Mars forward planning.

Asked about next steps, Dr. Noble explained that NASA has 90 days to formally respond; the expected formal response will be announced at a Town Hall in August. The Survey will guide NASA science for the next 10 years in planetary science, and there will be a mid-term review to assess progress. The Biological and Physical Sciences Division will release their own Decadal Survey in 2023, and Heliophysics will follow close behind, so there will soon be more community recommendations for SMD to consider.

Public comment period
Question: When will more information about HLS/SLD be publicly available?
Answer: This information is unavailable because it is an active procurement; there will be more information in late Summer.

Q: Will there be a response to the Endurance A rover concept?
A: This will occur in the process of the 90-day review.

Q: Will Gateway supersede the first Moon landing?
A: No, Gateway will be launched between the Artemis III and IV missions.

Q: Will HLS be a part of Artemis III?

Q from Gene Mikulka: Is it possible that because ESA is an agency and not a nation, it must go through signatory channels?
A: ESA and EU are not identical. EU cannot sign for individual countries, perhaps?

Q: When will Artemis III land on Moon, plus or minus 3 years?
A: The launch date for Artemis I will determine the launch dates for Artemis II and III.

Dr. George Sowers commented that the Decadal Survey (DS) failed to take up questions of economic geology, given that the Moon is rich in resources. This is science without an economic purpose. Dr. Noble noted that science wants to understand the origin and distribution of volatiles, and where there is some overlap between the science and economic value of lunar resources. Dr. Sowers felt there should be an effort to map and identify (lunar) resources. Dr. Noble pointed out that the CLPS mission, VIPER, as well as LRO, Lunar Trailblazer, and a number of other CLPS payloads are aimed at ground-truthing resources. Ms. Nancy Ann Budden commented that NASA's Exploration program office used to list economic objectives for lunar exploration, which eventually got dropped, adding that it does seem unrealistic, however, to expect that lunar resources could be extracted in a profitable manner. Dr. Bleacher said that this discussion illustrated why it is important to document objectives. SSERVI/STMD has a consortium that has a focus group (LSIG) that is having these discussions. Dr. Sowers reiterated that characterization and mapping of (economically important) lunar resources should be part of the science question.

Discussion
Dr. Noel Bakhtian cited one rationale of the lunar return as being a means of promoting peace through science diplomacy, and now that ISS is sunsetting, wondered whether there were a way to carry out science diplomacy through Artemis. Dr. Cerf said that one could argue that Artemis is already

accomplishing this end. Dr. Michael Liemohn noted that the Committee on Space Research (COSPAR) also serves a similar purpose.

Dr. Williams introduced the discussion on findings and recommendations, suggesting a first finding consisting of general plaudits for Artemis, tempered by concerns about science integration, as well as the program's impact on other, existing, missions, and future missions. Dr. Serina Diniega said that the Planetary Science Advisory Committee (PAC) meeting had heard a lot about plans for science integration, and had discussed a science objectives document that demonstrated some integration with Exploration. PAC feels that the effort is going in the right direction but is still concerned about connections. Dr. Cerf raised the issue of clashing commercial and science motivations. A meeting participant commented that lunar dust and its implications for both human and robotic exploration had not been much mentioned. Dr. Cerf noted that a mine on the Moon, and other such commercial missions, can impede science: how will this be managed? How will NASA cope with conflicts? Is there sufficient oversight for conflict at the AA level? Dr. Williams and Dr. Cerf commented that the Moon might serve as substrate for propellants (a lunar "gas station") but that the cost of water extraction via ISRU would be restrictive. Dr. Sowers said that it would be necessary to acquire the geologic knowledge to quantify the remote data; LCROSS measured 5.6% water by mass at the location of its impact. There are calculations of perhaps a billion metric tons (of water) per pole, enough to be economically interesting. If there's enough, this makes the question of propellant easy. Dr. Cerf reiterated that it would be necessary to factor in how much it will cost to extract water. Dr. Sowers noted that the key step is electrolysis, as demonstrated by the MOXIE technology demonstration at Mars. The science community can help illuminate the geology of the ice deposits: total area, depth, etc. Dr. Liemohn felt some of these questions might be covered in the recent Decadal Survey. Mr. Weiser noted that there are 8-9 undefined CLPS missions, which could conceivably get the desired answers. Ms. Budden thought ISRU could be a source of more answers, as the lunar South Pole is thought to have an abundance of PSRs with more ice, but these (water) sources have their own challenges. Dr. Sowers noted that an entire LSSW session had been devoted to this question, but it still seems like there is a gap for resource identification. PSRs are challengingly cold (40 deg Kelvin). Dr. Cerf asked whether the scientific missions relevant to ISRU are going to answer the quantitative questions being brought up in the current discussion. Dr. Liemohn asked: is it in NASA's interest to market the Moon? And is that in SMD's purview? Dr. Cerf asked :is it in NASA's interest to monetize the Moon, to help itself along? Dr. Sowers said that the presence of (economically) extractable water on the Moon could reduce the cost of propulsion to the Moon and back by a factor of 3. Mr. Weiser thought that the question is addressed in the Decadal Survey, and that there is a framework to answer the questions through CLPS. Dr. Williams added that Planetary Protection also needs to be highlighted. Mr. Callahan said there was a parallel question for Planetary Defense, but it is not necessarily a science question; it is more an issue of finding a "home" for the question. Mr. Weiser commented that CLPS companies can engage in this question independently as well.

Dr. Bakhtian suggested a finding on cross-cutting integration over directorates, and a recommendation to incorporate Lessons Learned from Mercury to Apollo, as well as to preserve them archivally. Mr. Mark McDaniel stressed the importance of the ability of SMD and HEO to inspire students to pursue STEM subjects, especially impressionable children in elementary and middle schools. The US is far behind in math and science in the US; the SC and HEOC are the two Committees best suited to inspire our youth and help our nation. Dr. Bakhtian suggested getting students into the DesertRAT analogs. Ms. Budden suggested the joint Committees write an observation that applauds the extent of interaction between science and exploration, given that there used to be a real disconnect. There is now a huge amount of communication and shared objectives. The integration strategy has been thorough, thoughtful and enacted well in advance of the missions. Dr. Diniega agreed, saying Artemis is showing how it can be done, and thought it was important to interact with the broader US community and reach out to underrepresented groups, as this is a real chance to change the culture. Inclusion plans should be in proposals, to make

everyone feel as though they belong and can make things possible. Dr. Williams felt that student involvement in analog projects could be especially helpful.

Dr. Bakhtian noticed that Aerospace hadn't been called out. Dr. Williams asked if there were any opportunities for the other directorates to be engaged with Artemis. Dr. Liemohn noted that lunar dust, which proved to be a huge contaminant for the Apollo program, is going to be a problem for devices, and for living. He felt that Dr. Bleacher's charts had demonstrated little acknowledgement of the problem. Dr. Cerf commented that Planetary Protection was only looking at biologics; what of commercial interests, or other scientific experiments, and the impacts of lunar surface exploration? Dr. Williams referenced a previous recommendation on Planetary Protection issues related to the destruction of the physical characteristics of surface that might be important for future missions. Dr. Cerf suggested there might be useful speculation on some resolution of this problem in select sci-fi scenarios.

Dr. Williams and Mr. Callahan discussed an action item, populating a list of projects from other parts of SMD, such as the HERMES space weather payload for Gateway, the ERSA internal dosimeter array, and several CLPS missions with cross-SMD payloads. Dr. Bakhtian asked: what we are losing in ISS and what are we picking up? And what of sustainability of Artemis across administrations? Ms. Budden noted that HEOC had made pointed observations about sustainability in the past. Dr. Patricia Sanders said that the Aviation Safety Advisory Panel (ASAP) has recently raised concerns about the "constancy of purpose" question, as well. Mr. McDaniel said that missions that transcend administrations are typically missions that inspire youth. Artemis is one of them; NASA should get more information about it into U.S. schools. Mr. Weiser suggested that the STEM committee be consulted on infusing Artemis presentations into school curricula. Dr. Bakhtian commented that a real date for the first Artemis launch would be helpful, even if it slips. Dr. Cerf asked if there were any tension between preparation for Mars exploration and preparation for the Moon: How does NASA prioritize one over another? Dr. Diniega felt the question meant that NASA messaging needs to be clearer, as both endeavors are important.

Mr. Hale proposed a joint finding stating that there is good cooperation and communication among SMD, ESDMD, and SOMD, as well as a recommendation to encourage NASA to use the excitement of the Artemis program and the science behind it to inspire young people in STEM, in order to provide robust civilian support across administrations. Mr. McDaniel agreed, saying that injecting enthusiasm for scientific discovery into youth is a natural way to help the mission transcend administrations. Dr. Bakhtian suggested a finding on science diplomacy, and incorporating Lessons Learned from the Apollo and Mercury programs, as well as prioritizing science and commercial interests. Ms. Budden noted that Lessons Learned (LLs) in the Exploration Office, in general would be helpful, as would LLs from Meteor Crater, Antarctic analog projects, as well as those on space suit testing and new gloves. Mr. Weiser supported more SMD Science Outreach programs, and getting some quantitative, economics-related answers on lunar resources.

Mr. Callahan adjourned the meeting at 5:05p.

Appendix A
Agenda

Appendix B
Attendees

Human Exploration and Operations Committee

Wayne Hale, ret. NASA, **Chair**
Nancy Ann Budden, Office of the Secretary of Defense
Stephen "Pat" Condon, ret. US Air Force
Michael Lopez-Alegria, Commercial Spaceflight Federation
James Voss, University of Colorado, Boulder
Mark McDaniel, McDaniel and McDaniel Attorneys, LLC
Lynn Cline, ret DAA, NASA HEOMD
Kwatsi Alibaruho, Industrial Sector Eaton
George Sowers, Colorado School of Mines
C. Douglas Ebersole, ret. US Air Force Research Laboratory
Ellen Stofan, Smithsonian Institution

Science Committee

Ellen Williams, University of Maryland, **Chair**
Noël Bakhtian, Lawrence Berkeley National Laboratory
Serina Diniega, Jet Propulsion Laboratory
Vinton G. Cerf, Google
Linda Godwin, University of Missouri
Michael W. Liemohn, University of Michigan
Sara Tucker, Ball Aerospace
Marc Weiser, RPM Ventures
Jason Callahan, Executive Secretary

Headquarters Attendees
Stephanie Dudley
Catherine Koerner
Jacob Bleacher
Sarah Noble

Webex Attendees
Lester Lyles, NAC Chair
Eracenia Kennedy
Enidia Santiago-Arce
Joan Zimmermann
Doug Ebersole
Chris Gilbert
David Kalen
Michele O'Connell
David Kalen
Narita Shinichiro
Hyuk Jeon
Ryan Whitley
Marcia Smith
B Harvey
Andrew Rothgaber
Beverly Perry
Francesco Bordi
Kailey Melton
Dillon MacInnis
Lewis Groswald
Michael Hollis
Robert Zimmerman
Max Tsuizaki
Jamie Favors
Jeff Foust
Mike DeKlotz
James Lochner
Rick Irving
Laurie Chappell
Steve Creech

Victor Schneider
Griffin Reinecke
Allison Hannah
Danny Lentz
Zudayyah Taylor-Dunn
Evan Matsuda
Kailey Melton
Tonya Woodbury
Lisa Watson-Morgan
Mike Ching
Aaron Grant
Barbara Adde
Patricia Sanders
Etienne Dauvergne
Stephan Gerard
Mark Kirasich
James Spann
Kelly O'Rourke
Barbara Zelon
Alicia McPhail
Gene Mikulka
Ann Zulkosky

Zachary Pirtle
Timothy Lewis
Matthew Schreiber
Peter Devlin
Renee Pullen
Erin Mahoney
James Armitage
Laura Forczyk
Ashlee Wilkins
Stephanie R Buskirk Dudley
Anthony Latimer
Dana Engle
Todd Parks
Chris Scarpelli
David Steitz
Dennis Feerick
Rick Irving
James Armitage
Samuel Lawrence
Mark Kirasich
Dana Engle
Christine Joseph

Hemil Modi
Andre Lovas
Vanessa Lloyd
James Spann
Samuel Lawrence
Kendahl Hejl
Daniel Hartman
Maria Collura
Holly Ridings
Etienne Dauvergne
Chris Gilbert
Bill Clark
Gale Allen
Melissa Six

Appendix C

HEOC Membership

Mr. Wayne Hale, Chair

Ms. Nancy Ann Budden
Director for Special Operations Technology
Office of the Secretary of Defense

Dr. Stephen "Pat" Condon
Aerospace Consultant, former Commander of the Ogden Air Logistics Center,
the Arnold Engineering Development Center
Air Force Armament Laboratory

Mr. Michael Lopez-Alegria
Former NASA astronaut and retired U.S. Navy Captain
President of the Commercial Spaceflight Federation

Mr. James Voss
Former NASA astronaut and retired U.S. Army Colonel
Department of Aerospace Engineering Sciences,
University of Colorado, Boulder

Mr. Mark McDaniel
Partner at McDaniel and McDaniel Attorneys, LLC.

Ms. Lynn Cline
Former NASA Deputy Associate Administrator
Human Exploration and Operations

Mr. Kwatsi Alibaruho
Vice President, Program Management
Industrial Sector Eaton

Dr. George Sowers,
Professor
Colorado School of Mines

Mr. C. Douglas Ebersole,
Former Executive Director
Air Force Research Laboratory

Dr. Ellen Stofan,
Under Secretary for Science and Research
Smithsonian Institution

Appendix D
Presentation Material

1. Moon to Mars Architecture; *Cathy Koerner*
2. Cross-Directorate Science Utilization; *Jacob Bleacher*
3. Artemis Science Team Formation; *Sarah Noble*
4. Integration and Implementation of Science in Artemis; *Stephanie Dudley*
5. Discussion of Planetary Decadal Survey; *Sarah Noble*

Appendix E

Chat from the Webex

from Mike Ching (Ext) to everyone: 2:50 PM
the LSIC (Lunar Surface Innovative Consortium) also notifies their community of the LSSWs
from James Spann (Ext) to everyone: 2:53 PM
The space weather relevant efforts are geared toward protective human and robotic explorers.
from b harvey Ext (Ext) to everyone: 3:00 PM
Safety zones are part of the Accords to protect against interference.
from lester.lyles (Ext) to everyone: 3:11 PM
The Artemis Accords are designed to negate or resolve issues / scenarios like those that Vinton Cerf mentioned. We owe you all a better answer on how the Accords will work. We should ask Karen Feldstein , the NASA focal point for International activities , to provide the NAC with an Artemis Accords summary ,and how it will work for potential scenarios like Vinton's.
from b harvey Ext (Ext) to everyone: 3:14 PM
Payload integration manager a great first step to commercialization.
from Serina Diniega | she/her (Ext) to everyone: 3:22 PM
And State of the Profession
from b harvey Ext (Ext) to everyone: 3:34 PM
19.6 very nice for widest spread of tech
from Aaron Grant (Ext) to everyone: 3:38 PM
When will more information about HLS/SLD be avalible?
from bEGEucws379 (Ext) to everyone: 3:39 PM
Can you discuss NASA's response to the Endurance-A rover concept?
from b harvey Ext (Ext) to everyone: 3:39 PM
So Gateway will supersede Moon landing?
from Gene Mikulka (Ext) to everyone: 3:40 PM
On the Artemis Accords that Dr. Cerf mentioned: Question: Is it possible that since esa is an agency and not a nation that cannot sign on behalf of the member nations and that has to go though diplomatic channels?
from Noel Bakhtian (Ext) to everyone: 3:42 PM
Is there an estimate range of years to expect when Artemis 3 landing on moon?
from Kwatsi Alibaruho (Ext) to everyone: 4:07 PM
As always, I have been tremendously energized by and impressed with what these NASA leaders are doing. I have great passion around making sure that my feedback is value added, so I will give serious thought to properly framing my recommendations and socialize that will my colleagues and Committee Chair promptly.
from Serina Diniega | she/her (Ext) to everyone: 4:09 PM
This is an excellent point and one that extends (would be analogous to?) challenges with Mars exploration as well
from Serina Diniega | she/her (Ext) to everyone: 4:10 PM
VIPER: Volatiles Investigating Polar Exploration Rover
from Serina Diniega | she/her (Ext) to everyone: 4:10 PM
https://www.nasa.gov/viper
from ENIDIA SANTIAGO-ARCE Int (Ext) to everyone: 4:10 PM
Volatiles Investigating Polar Exploration Rover,
from Serina Diniega | she/her (Ext) to everyone: 4:14 PM
Speaking from a Mars perspective - those types of measurements are high priority, but their acquisition itself is not a science question, those are measurements that feed into addressing a science question.
from Serina Diniega | she/her (Ext) to everyone: 4:15 PM
So you may not see them at the question descriptions, but that doesn't mean they aren't in as science priorities
from Serina Diniega | she/her (Ext) to everyone: 4:36 PM

They should be
from Serina Diniega | she/her (Ext) to everyone: 4:49 PM
It's always 20yrs off ...
from Noel Bakhtian (Ext) to everyone: 4:50 PM
like fusion. like hypersonic civilian flight.
from Serina Diniega | she/her (Ext) to everyone: 4:58 PM
If you're getting at making sure to include underrepresented groups, you can include "Inclusivity" which is now a NASA value