National Aeronautics and Space Administration
Washington, DC

NASA ADVISORY COUNCIL
Human Exploration and Operations Committee

May 15-16, 2023
NASA Johnson Space Center
Houston, TX

MEETING MINUTES

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

Public Meeting Minutes
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Meeting Report prepared by
Joan M. Zimmermann, T&J, LLC

May 15, 2023

Call to Order/Announcements

Dr. Bette Siegel, Executive Secretary of the Human Exploration and Operations Committee (HEOC), called the meeting to order, provided details of Federal Advisory Committee Act (FACA) rules, and made administrative announcements. She introduced the Chair of the HEOC, Mr. N. Wayne Hale. Mr. Hale welcomed members to the meeting, relating that he had come to work at the meeting site, Johnson Space Center (SC) 45 years earlier, at a time when the NASA Advisory Council (NAC) was chaired by Walt Williams, an early manager of the Mercury project. He encouraged HEOC members to interact with young staff at the Center, to encourage them in their future endeavors.

Status of ESDMD

Mr. Jim Free updated the status of the Exploration Systems Development Mission Directorate (ESDMD), first reviewing the principal ESDMD goals: to build a sustainable Artemis Architecture; align and support NASA Moon to Mars objectives; move toward a more affordable Exploration Crew Transportation System; foster high standards of program and project management; align Artemis programs to balance funding profiles within the available budget; collaborate with Centers to maintain a highly skilled workforce; and clearly communicate status and plans for all stakeholders. Mr. Free noted that Ms. Vanessa Wyche, JSC Center Director, has been a great partner with ESDMD, in collaboration and open communication. Dr. George Sowers asked if sustained presence on the Moon was contained within the Directorate's objectives. Mr. Free affirmed this was the case, as the Directorate has an explicit objective of near-term presence of crew for 30 days on the lunar surface, with robotics in their absence.

With the Space Operations Mission Directorate (SOMD), in response to the NASA Authorization Act of 2022, ESDMD has established a Moon-to-Mars (M2M) program office. Last year, NASA decided that to ensure the successful execution of Artemis missions, the former Human Exploration and Operations Mission Directorate was to be split into ESDMD and SOMD; Congress has since approved further refinements on the ESDMD/SOMD reorganization. Mr. Free displayed the current organization chart for ESDMD, led by the Office of the Associate Administrator, under which resides the Strategy and Architecture Office, the Moon to Mars Program Office (all Artemis and Mars mission work); and the ESDMD Business Office (with some functions working up and out with Chief Financial Officer, communications, and NPR 7120.5). Mr. Free clarified that contracts are not held by the Business Office, but by the programs at the NASA Centers.

The next step down in the organization chart contains the Mars Campaign Office, which focuses on the next step of technology development and implementation, and is connected to what the NASA is doing on the lunar surface relative to future Mars exploration. Safety and Mission Assurance are traditional functions under this office. The Systems Engineering and Integration (SE&I) Office focuses on the heavy technical integration work for the more complex missions with human elements. The structure retains each manager for each Artemis mission. The responsibility for global risk management is within the M2M program office. All of risk management, and all programmatic and technical comes to the Deputy Associate Administrator (Mr. Amit Kshatriya). Mr. Kshatriya added that in order to give program and project leads some flexibility, risks will be aggregated in a risk board. ESDMD is taking some time to think this through, with implementation details to be determined. Exploration Operations, based at JSC, is responsible for mission operations and product development; Director Wyche is in the process of choosing a leader for this office. The Program Planning and Control Office (PPCO) has traditional functions. There will also be a PP&C office function for each of the programs, which all roll up to the M2M PP&C. There are no changes to the other programs, which still reside at the Centers (Gateway, Human Landing System, etc.) Interfaces with the Science Mission Directorate (SMD) and the Space Technology Mission Directorate (STMD) are included in both the M2M program office and the ESDMD Strategy and Architecture Office.

Mr. Hale asked if there were a parallel handover mechanism in the Flight Operations Directorate (FOD). Mr. Free said that FOD is just one element of Mission Operations. Ms. Wyche offered a Space Shuttle analogy, in that the organizational structure gives authority to the implementing arm. Mr. Hale observed that ESDMD is top heavy with ex-flight directors and SOMD is top heavy with ex-astronauts. Mr. Free

said that the directorates are not truly divergent, and that it is incumbent upon the Associate Administrators (AAs) of ESDMD and SOMD to integrate together. Each of the programs will still have an operations element to them; there is no duplication, but coordination. The Kennedy Space Center (KSC) Ground Operations program is still stand-alone, but it has an interface with ESDMD with respect to vehicles. Mr. Sowers asked where the end of technology pipeline comes in to the Directorate. Mr. Free indicated that the pipeline feeds to the Strategy and Architecture Office, for example, in the case of fission surface power reactors; the SE&I Office will come in when NASA actually flies the reactor. Mr. Sowers noted that it was important to have a pull function for technologies such as in-situ resource utilization (ISRU).
Mr. Hale commented that organization is key to making the whole enterprise work, and that ESDMD looks at first blush to be an excellent organization.

Mr. Free presented details of the Program Financial Plan and the ESDMD budget from Fiscal Years 2024-28 (FY24-28), showing a budget of roughly $8B to 8.6B into the outyears. For 2024, the President's Budget Request (PBR) provides $7.9B for Deep Space Exploration Systems. Dr. Patricia Sanders commented that budget is really key, and it is important to be honest about what can be done with available resources. Mr. Free agreed that if NASA plans to go to Mars in 2039, it will have to put that budget together now. Dr. Pat Condon asked: what efforts are under way to ensure that Congress understands the impacts of budget instability? Do they hear the message? Mr. Free said that NASA conveys the impacts of the budget and reiterates when necessary. All NASA can do is quantify the impacts as best it can. Paraphrasing Dr. Bobby Braun, Mr. Free said that NASA has spent 3 years on a Continuing Resolutions, while its "competitors" have not. Mr. Kwatsi Alibaruho asked if there was a significant variance between the PBR and what NASA actually needs. Mr. Free said there will always be differences, but that the NASA Administrator definitely went to bat for NASA during the last budget cycle. Mr. Hale commented that the kind of space program NASA has depends on the desires of the taxpayers, and this is one reason for NASA to promote commercial space. Dr. Sowers questioned the affordability of the space transportation system: is $3B-3.5B per year enough to support the cadence of one mission per year? Mr. Free noted that affordability initiatives for the Space Launch System (SLS), Orion, etc., are varied and not completely captured in the briefing charts, and include some transitions to contractors. The FY24 budget includes some funding changes in the Common Exploration Systems Development (CESD) and Artemis Campaign Development (ACD) budget lines, related to Gateway and the development of the Mobile Launcher-2 for the Artemis IV mission. The Artemis IV mission is moving out by about 9 months to September 2028. Mr. Free said it has been frustrating to have to keep three manifests, given the complexities of the PBR, current budget, and alignment with contract dates. The Artemis program is not solely in ESDMD; it is meant to achieve all the objectives the Agency has put in place.

ESDMD has been tasked to develop and own the NASA Moon to Mars Strategy architecture, but in concert with all the mission directorates, using an "Architecting from the Right" approach that allows objectives (Science, Infrastructure, Transportation and Habitation, and Operations) to be satisfied in multiple ways through implementation of various missions. Everything is connected. The first set of products is now online: these are the Architecture Definition Document; the Moon to Mars Architecture Summary; and six white papers. [[www.nasa.gov/MoonToMarsArchitecture]] After an initial Architecture Concept Review (ACR) in January of 2023 there will be annual ACRs each November to align plans with the budget.. This summer, NASA will be setting up workshops to get engagement and feedback from stakeholders.

Mr. Free said that the involvement of international partners in the Artemis program is very different from the Apollo era, in that they are critical to the current effort. Orion European Service Modules are now in production through Artemis VI. The Gateway space station's International Habitation Module, Canadarm 3, the European System Providing Refueling Infrastructure and Telecommunication (ESPRIT), and HTV-XG (JAXA's cargo spacecraft) are also in production.. Study agreements in place for a pressurized lunar

rover, surface habitation elements, a lunar cargo lander, and a lunar utility rover. Logistics are becoming a big driver for the program, and much future work is in discussion with partners.

Dr. Ellen Stofan commented that she was impressed by the work. Ms. Lynn Cline expressed interest in how many international partners were involved. Mr. Hale asked how the Artemis Accords affect ESDMD. Mr. Free said that NASA is looking for ways to include those countries that cannot bring billions of dollars to the table, by involving them with science. There are other international partners who want to bring elements to the table, and they are aligned with NASA objectives.

Mr. Hale noted that HEOC has had a long-standing recommendation for an annual cadence of flights, as it is difficult to maintain proficiency with a very low flight rate. The longer the interval between missions, the harder it is to develop the "muscle memory" to perform missions. Once a year is probably the minimum cadence needed to help fight against the accumulation of human error. Mr. Free said that that the leaders of the Centers are well aware of the need for a regular cadence, while simultaneously dealing with building a new launch vehicle and a new capsule. There is also a very structured Lessons Learned process going on now, from the technical details all the way up to the Office of Communications. Ms. Nancy Ann Budden said she had heard a concern about pulling the Centers together, and recalled that in prior years, NASA experienced the same issue. To facilitate coordination, there were working groups, involving all the Centers, meeting a week per month, an exhausting but very effective effort. Communication is everything. Mr. Free agreed that one of the critical AA tasks is to both communicate and engage with Center Directors, that there is a lot of improvement possible in engaging regularly with SOMD, as well as with contractors. Ms. Budden suggested that in the spirit of transparency, Mr. Free should invite all representatives that have a stake in the process to regular meetings. Mr. Free concurred, adding that it is vital to support the folks pushing the ball down the field. Mr. Sowers noted that there to be a three-year gap between Artemis III and IV. Mr. Free said that the Directorate knows that it must be very deliberate about the manifest, while meeting challenges with the SpaceX lander, and suit development. A backup plan will be necessary for maintaining proficiency, and NASA must also find ways to keep good people on staff. Dr. Sowers recommended using the risk management process to help address these issues.

Moon to Mars Program Office

Mr. Amit Kshatriya provided an update on the Artemis missions. Artemis I achieved all of its objectives, representing a huge achievement for everyone across the Agency, and the many US businesses involved in the hardware production. There were many small businesses involved, including "mom and pop" shops, with a total of 3000 suppliers in all 50 states, and across the Atlantic. So many people felt a part of the mission. In addition, every dollar that comes out of the Treasury for Artemis goes back into it three times over. Mr. Hale gave kudos to the person who attached the camera to the Orion capsule.

Artemis I accomplishments included demonstrating that the Orion heat shield can withstand conditions for Earth return, certification of an optical navigation camera, and characterization of a solar array wing camera. A Post Flight Assessment Review (PFAR) for flight elements is conducted after each mission: the Artemis I Exploration Ground Systems (EGS) PFAR is complete, and the Orion PFAR is due to be completed on 7 June. Mr. Alibaruho asked for a sense of turnaround on Lessons Learned in hardware. Mr. Free said the process was way out in front on the hardware; Lessons Learned will be aggregated by October. The team is very well integrated. Dr. Sowers asked how the capsule had fared in the environment. Mr. Free said the space did very well, from a model standpoint, in terms of environment. There were very few component recalls, and a plume analysis is still in progress.

The Artemis II mission will be the first crewed test flight to the Moon since Apollo, targeting a distance of 1200 nautical miles in a highly elliptical orbit for 24 hours. Rendezvous techniques are expected to be fairly simple in a relatively low-torque environment. The 10-day mission will not include injection into lunar orbit, and will use free return from the time of trans-lunar injection (TLI). One of the major milestones accomplished thus far for Artemis II is crew selection. The crew has started training, and the Mobile Launcher 1 (ML-1) refurbishment is on track to support Artemis II processing. There will be a

Mission Integration Review in June, and the mission will do a delta as needed. The team is trying to do as much work as possible at the Michoud facility. Everything is on track for a November launch. Mr. James Voss observed that a free return trajectory is a conservative approach, and asked if there had been any discussion about doing extra burns. Mr. Kshatriya said it was tough to change trajectory on the fly. The Artemis I mission took the vehicle to the edge of its thermal limits. Fiddling with the Orbital Maneuvering Service (OMS) engine is not under discussion yet. For a near-rectilinear Halo orbit (NRHO), there is a six-day abort window, which puts some constraint on experimentation. Mr. Hale asked if everyone was satisfied about the status of debris around the Mobile Launcher and tower. Mr. Kshatriya said that a FOD Tiger Team is categorizing every piece of debris that came off Pad B. Mr. Douglas Ebersole asked how many new risks had been identified. Mr. Kshatriya said he would get that data back to the HEOC, and that plans were under way to re-open virtually every Artemis I risk.

The Artemis III mission will be the first landing attempt on the Moon. The Orion vehicle and lander will be inserted into a NRHO orbit, an orbit that constrains some return opportunities while providing more access to the lunar surface. The mission is working on getting more fidelity on interfaces. The SE&I challenge for Artemis III is not trivial. Approaches to both acquisition and interrogating the engineering baseline are different between NASA and SpaceX, but thus far there has been great communication between the Program Office and vendors. There will also be dual launch campaigns. Hardware is moving along well. In both the Science and Exploration Directorates, there is huge interest in returning volatiles samples. The Volatiles Investigating Polar Exploration Rover (VIPER) is still on track to reach the Moon before Artemis III. Mr. Kshatriya said there will be many Commercial Lunar Payload Service (CLPS) launches in 2023 and 2024, providing a long enough lead time to ensure the local environment will be understood before Artemis III. The docking system will be using some heritage from the International Space Station (ISS, or *Station*); the hope is to wrap it up by the end of the year. For the Space Launch System (SLS), all Artemis III hardware is in flow. Asked if there were any details on the Human Landing System (HLS) campaign, Mr. Kshatriya said there were none his presentation, but that SpaceX test flew the Starship in April and reached a 39km apogee. SpaceX remains an integral partner in the Artemis program. Mr. Kshatriya said he would be happy to bring back more details at next meeting. Dr. Sowers asked how NASA is involved in the recovery aspect of SpaceX flights. Mr. Kshatriya said that NASA is fully partnered with them in how the data is analyzed. Mr. Hale commented that, as in Apollo, the lunar lander is the biggest challenge. Mr. Kshatriya agreed, adding that because of this critical path item, NASA is bringing in all its contractors, and will choose missions based on the hardware that is available. Asked if Artemis III will be the last Interim Cryogenic Propulsion Stage (ICPS). Mr. Kshatriya said Yes, as far as Artemis goes. On the suit side, Axiom has just unveiled their suit and is starting fabrication.

The Artemis IV mission will visit a south polar region, similar to Artemis III. International partners will be well represented in this mission as they will be contributing heavily to the first use of Gateway through ESA's provision of the I-HAB to be integrated with the Power and Propulsion Element (PPE), and Habitation and Logistic Outpost (HALO) components on that mission. Artemis IV status (slide). Much progress on SLS for this mission has been made. The ML-2 international Critical Design Review (iCDR) board was held in March. Primary steel and tower production is scheduled to begin this summer.

The Artemis V mission will include the delivery of the European component, ESPRIT, to Gateway, followed by lunar landing; another lander provider will be used for this mission. Long-lead items for SLS 4-6 are in process. Artemis V will have the first RS-25 re-starts. Mr. Hale asked if these were the new RS-25 expendables. Mr. Kshatriya confirmed that the expendable RS-25s are being qualified right now.

In other activities being undertaken by the Mars Campaign Office, risk mitigation is being achieved through continuing flight projects. Recent successes include the performance of the CAPSTONE cubesat, the Radworks instrumentation, and Shadow Cam during the Artemis I mission. The tech demo, Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), continues to operate on the surface of Mars. Ongoing topics for future Mars exploration include the evolution of the Environmental Control and Life Support System (ECLSS) aboard ISS, logistics reduction, and the refinement of spacecraft fire systems, spacesuit physiology, and spacecraft food and medical systems.

Mr. Hale asked how science was influencing Artemis missions IV-VI. Mr. Kshatriya said that a science and technology utilization document provides requirements that start from the top. Dr. Condon asked if there were a role for Artificial Intelligence (AI) in the Mars mission areas. Mr. Kshatriya said that autonomous systems will be very important to Mars missions, from both an operations and a data/image processing standpoint. There are touchpoints with the Ames computing centers and with industry in this area. Mr. Alibaruho asked Mr. Kshatriya to name the top three risks for Moon to Mars at present. He replied that flight cadence and the budget to support flight cadence constituted the main risk. He added that lander technology development, development risks for SLS block 1B, the ability to navigate lunar polar regions (very different from equatorial exploration), and development and reliability challenges associated with Gateway dormancy periods were also risk areas, but SE&I helps tremendously in mitigating these risks. Dr. Sowers noted that in the area of lander development, there have been three consecutive failures in launching a lander to the Moon in recent years; does NASA have insight into these failures? Mr. Kshatriya said the CLPS program would be able to provide these insights. Mr. Hale asked if there was any other research in progress for protecting the crew against radiation during transit. Mr. Kshatriya noted that Artemis I was heavily instrumented to measure radiation exposure, and satellites outside the Van Allen belts provide other data. Ms. Cathy Koerner commented that the Human Research Program has been focusing efforts on burning down risk for a Mars cruise. The risk spectrum is pretty broad, and is rooted in current experience in Low Earth Orbit. Mars is very different; the crew will experience a 2-3 year exposure to a radiation environment that is not well characterized at present. There will be analogues on the lunar surface, but as yet, the radiation risks are not well known. Mr. Kshatriya said the Moon to Mars program will collect as much data as possible in terms of shielding, shelters, and other means of protection against radiation. Mr. Alibaruho asked: what's your view of the labor market re: skills? Is engagement going well? Are the skill sets there? Mr. Kshatriya said that craftspeople, especially in the areas of metal forming, 3D printing, and high-precision welding, are in high demand, and they are hard to find. NASA will need to build capacity. The primes in the space industry are starting to invest to help build that capacity. These ambitious missions will help bring the workforce along. Ms. Budden asked if NASA was investing in scholarship and education programs, with an eye to supporting workforce development. Mr. Kshatriya said the NASA STEM office and the Science Mission Directorate (SMD) supports some scholarship programs, and recommended further consulting Dr. Nicola Fox, the new SMD AA. Mr. Hale recommended consulting NAC member, Dr. Dan Dumbacher. Ms. Budden suggested exploring other programs and partnerships, including educational outreach efforts in the Department of Defense (DoD). Mr. Kshatriya commented that each NASA mission births new scientists into the world. Mr. Hale took an action invite Mr. Mike Kincaid of the NASA STEM Office to brief HEOC. Ms. Budden noted that it's still true that everyone wants to team with NASA.

Strategy and Architecture

Ms. Catherine Koerner provided an update on strategy and architecture efforts to identify deep space exploration priorities. Exploration in deep space has been endorsed by more than one administration and confers numerous benefits to humanity, through contributing to science, providing inspiration, and maintaining and improving the national posture. ESDMD must emphasize all these aspects. NASA's Moon to Mars Strategy and Objectives provide a blueprint for future human exploration, to be achieved by "Architecting from the Right" (looking to future goals), and meeting objectives by executing from the left. The goals and objectives of the Moon to Mars Strategy are broken down into four categories, namely Science; Lunar and Mars Infrastructure; Transportation and Habitation; and Operations, which are aligned with NASA's four main directorates. NASA has been executing this strategy over the past year, while integrating human and supporting robotic science needs using the Architecture Concept Reviews to document progress in the Moon to Mars Architecture Definition Document (ADD).

NASA held an Architecture Concept Review in early 2023 (dubbed ACR22 as it was based on the 2022 Strategic Analysis Cycle), the first of what will become an annual cadence of reviews. Future reviews are to be held in November to help feed the budget cycle and to attempt to align budget with the vision/missions of the exploration program. ACR 22 focused on the Human Lunar Return segment of the

architecture. The next phase will be focused on expansion of the Humans to Mars objective decomposition and segments needs. ACR 22 focused on the architecture process, initial capabilities and the disposition of key issues from an ESDMD-001 Moon to Mars (M2M) Architecture Definition Document (ADD) Change Request. Through the ACR process, NASA will also be discussing sub-architectures such as those that govern communications, positioning, and navigation and timing technologies. Mr. Hale said that there appear to be two schools of thought on exploration: some who want to get to Mars as soon as possible, and others who want to spend more time on the Moon. Ms. Koerner said that the intent is to go to the Moon and stay, but not at the expense of going to Mars. The journey to Mars also depends on the evolution of what industry and international partners can contribute to the effort, as well as the needs and plans of the many different stakeholders. Ms. Budden commented that lunar demonstrations can help get NASA to Mars. Ms. Koerner agreed, adding that some objectives serve both purposes and are indicated as such. Dr. Sowers, referring to the presented charts, asked for confirmation that NASA was not skipping the middle two segments (Foundational Exploration and Sustained Lunar Evolution). Ms. Koerner said that NASA was absolutely not going to omit these segments.

The Human Lunar Return segment includes EGS, Orion, SLS, Gateway, Deep Space Logistics, CLPS, HLS, and the evolving Extravehicular Activity (xEVA) systems. The Moon to Mars campaign segment is currently being fleshed out. “Architecting from the Right” does not omit Human Lunar Return and Sustained Lunar Evolution as the process moves from left to right, but rather will evolve through all the different phases of the architecture. There will be a stepwise process of buying down the risk of sending humans to Mars. Ms. Koerner stressed the chart is still notional and that any campaigns beyond Human Lunar Return are still government reference missions.

ACR public products, at present, include a detailed 150-page technical document; a Moon to Mars Architecture Summary, and six white papers, which can be found at [[www.nasa.gov/MoonToMarsArchitecture]]. There are other lower level documents that capture training systems; the training needs come out of the human systems needs. The Architecture Definition Document is not a requirements document. It is meant to set the stage for how NASA executes the Moon to Mars campaign at a high level. The Architecture Definition Document is not intended to be a “shall” document.

NASA recognizes that Moon to Mars cannot be done alone. There are numerous areas for collaboration from both industry and international partners: power infrastructure and distribution, robotics and mobility, communications, lunar environment mitigation, and others. Dr. Sowers commented that ISRU should be added to the list. Ms. Koerner said ISRU is implied in some areas, and that it is under discussion. NASA is planning to have a workshop at the end of June to solicit feedback. Ms. Koerner closed by asserting that the Artemis generation has indeed arrived.

Mr. James Voss asked how the ESDMD/SOMD reorganization has been working thus far, and how SOMD will receive all the information ESDMD has been working on. Mr. Free said that to date, the two directorates have been integrating over issues, such as crew and international partner agreements. He said he would like to see more run time, but that thus far, there have been no stumbling blocks. Dr. Sowers felt that the value of the Moon is in its material resources, and thought that Mars would remain unattainable until resources at the Moon can be developed to provide propellant, particularly as it is estimated that a single Mars mission will cost $100B. Mr. Free thought the scientific value of the Moon is significant, particularly at the south pole, as it will yield 4-4.5 billion year old samples. The most recent (Planetary) Decadal Survey supports lunar science goals as well as Mars science goals. Mr. Alibaruho approved of the ACR process for getting alignment strategically; he asked if any gaps had been closed as a result of ACR22. Ms. Koerner commented that ACR22 identified a strong need for the science and ISRU communities to take advantage of large quantities of lunar sample; the ISRU community in particular might be able to find a good site to build a power plant on the lunar surface. The review also identified new stakeholders by way of the ACR 22 process. Ms. Koerner thought there were many more fruits to be obtained. Mr. Alibaruho asked: how about logistics (systems to get from point A to point B) and storage? Has there been more forethought on this subject than in previous years? Ms. Koerner thought ACR22

identified logistics as a weakness and that it needs more attention. At present, logistics is missing for everything except the human element. Mr. Ebersole commented that the ADD is an outstanding document, and that its elements need to be studied as to where they compete and complement. Ms. Budden offered kudos on the successful reorganization process. Dr. Sanders said she would be interested in how one goes from needs to "shalls." Mr. Hale aired his concern about the lander development process, and thought HEOC might do well to issue a recommendation on a public definition of the risks involved with HLS development. Mr. Free agreed that a lot had to happen: SpaceX must carry out multiple launches, demonstrate ship-to-ship cryofluid transfer, and demonstrate an uncrewed flight before HLS risks can be truly understood. Dr. Condon applauded the excellence of the presentations.

Joint Meeting with Technology, Integration, and Engineering Committee (TI&E)

Mr. Mike Green, Executive Secretary of the Technology, Integration, and Engineering Committee (TI&E) introduced a joint meeting of the HEOC and TI&E. TI&E Chair, Mr. Michael Johns, made brief remarks.

Moon to Mars Architecture Process Overview

Ms. Nujoud Merancy, representing ESDMD, introduced an overview of the Moon to Mars architecture process. Who, What, When, Where, and Why questions inform the architecture. The Why is to explore; the What is a long-duration exploration of the lunar surface; the Where is the lunar south pole. How to get to this destination and how to return are the subject of six white papers produced by ACR22, which cover such subjects as a systems analysis of architecture drivers, the functions of Gateway, and Mars forward capabilities that must be tested at the Moon. Key components of the approach include a breakdown and analysis of traceability, the architecture framework, and processes and products. Ms. Merancy, in response to a question, said that NASA has been holding industry workshops to socialize the contents of the white papers ahead of any request for proposals (RFPs), an intentional outcome of these papers.

The "Architecting from the Right" approach takes the characteristics and needs of the Moon to Mars endeavor, links them to the requirements, and traces them up to the objectives and goals. An example given is the Transportation Goal 1 (Orion and HLS). In the framework, this example can be broken down into segments and sub-architectures. Transportation systems contains common functions (slide), and some segments are nested. The Architecture iteration process has the objectives decomposed into use cases and functions. Element allocations and traceability are performed to an initial segment; followed by program requirements; unallocated functions (gaps); and trades and analysis. As the definition of the next segment and included elements is completed, the process is repeated as necessary to close out gaps and fill out the system needed to get from Moon to Mars. This process closes out the system from both the left and the right.

Mr. Hale asked: why does NASA want a sustained lander? Where do you get the requirements for a second one? Ms. Merancy said that because the act of transporting crew can be met by more than one vehicle, NASA is buying services for this function, and wants to have competition for the long term. While not a general principle, NASA is employing a similar approach for suits, and it is a strategy for the mission directorate as a whole. Dr. Sowers asked if different architectures were being considered. Ms. Merancy said that the Mars Transportation System has a wider aperture of study; that's where the white papers come in, to provide a rationale behind those systems. While NASA can't direct any work involving industry, the Agency is getting a look at what is out there. Dr. Sowers cautioned against "just picking a widget." Mr. Voss commented that it might be necessary to select widgets that must subsequently be inserted into the architecture (e.g., Orion and SLS), and asked how these existing systems are meshed this into the architecture approach. Ms. Merancy noted that many of the papers treat this problem. Mr. Voss commented that some things are already on the left of the architecture framework, and asked how they can be inserted into the middle of the architecture. Ms. Merancy did not think the use of Orion and SLS overly constrains the Mars mission. Dr. Sowers asked why Starship, if successful, shouldn't be used to get directly to the Moon or Mars. Ms. Merancy noted that the benefits of technology and innovation can be infused throughout the whole process of moving through the architecture. For example, Human Systems was added to address ADD comments and will be refined in ACR 23.

Ms. Merancy closed by displaying details of Human Lunar Return (HLR), a crewed initial lunar surface reference mission, which contains foundational exploration segments that build out to the 30-day mission. Dr. Condon asked if there were other Moon-to-Mars challenges that rise to the level of the radiation risk. Ms. Merancy said that transition from zero gravity to microgravity, the characteristics of long-duration missions, and food systems were similar risks to radiation risk.

Mr. Walt Engelund, of STMD, covered the transition and infusion of technologies into the Artemis missions. STMD is building upon a Strategic Technology Framework, which focuses on developing human and robotic technologies, as well as cross-cutting technologies. The NASA Moon to Mars Strategy and Objectives is a set of 63 top-level objectives spread across 10 top-level goals, all of which are coordinated through a Federated Board (FB), comprised of representative from all five mission directorates. Over the last year, STMD has been working on the M2M Blueprint Objectives. STMD is aligned with ESDMD M2M and Artemis development through numerous avenues, including direct architecture support and input, document reviews, and regular meetings. The Space Technology portfolio is comprised of such areas as nuclear fission surface power and propulsion systems, ISRU, infrastructure, habitation technologies, and advanced deployable solar arrays. STMD runs the Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR) programs for NASA, which aid in shepherding technologies from low to high Technology Readiness Levels (TRLs). Mr. Alibaruho asked what NASA is doing to drive results in the early stages of technology development; i.e. what is the forcing function? Do you operationalize quickly, try something, fail fast? Mr. Engelund said STMD does try many things, depending on the program and TRL. For example, they do not typically provide a lot of oversight to university grants, which can sometimes provide high-payoff results. STMD's Early Career Initiative (ECI), targeted to post-graduate NASA researchers, places a lot of emphasis on training in project management, and how to propose and stand up projects. It depends on the program and the activity. Ms. Jenn Gutestic noted that NASA recognizes that the early stage portfolio is an area where STMD can invest in both pull and push technology development, a good example being the Roll-out Solar Array (iROSA). These arrays were developed over a decade's time, with about 40 SBIRs. Mr. Engelund added that Maxar Technologies picked up STMD's demonstration solar arrays (iROSAs), which are now deployed on ISS as operational arrays. SMD's Double Asteroid Redirection Test (DART) mission used iROSAs, and Gateway has baselined them for use as well. The technology has been acquired by Redwire Corporation, and is a good example of a long-term investment. Mr. Jim Reuter commented that sometimes NASA uses multiple companies and partnerships for such technology development. Dr. Condon asked how technology can drives exploration. Mr. Reuters felt that technology drives exploration and vice versa. Dr. Sowers asked what the success rate was, from far left and into a program. Mr. Reuters said that one metric of success is tracking infusion points (wherein a company has picked up the technology). There have been over 1000 infusion points in the 12 years of STMD history. Ms. Gustetic said there had been 13 or 14 infusion points for and STMD funded technologies that were utilized on the Mars Perseverance rover. STMD also tries different approaches during the technology "Valley of Death" (TRL 3-6) phase of technology development .

Mr. Engelund described efforts under the Space Technology Research Grant (STRG) system, a university solicitation named Lunar Surface Technology Research (LuSTR), aimed at developing technology areas like ISRU, thermal mining, water regolith analysis, surface power systems, and site preparation and excavation. The LuSTR 2023 call just received proposals in three topic areas; Active Dust Mitigation, Lunar Extreme Access and Exploration via Cooperative Multi-Robots; and Extraction of Metals from Lunar Regolith for Additive Manufacturing. All these topic areas potentially feed forward to sustaining a lunar and Mars infrastructure. Through an agreement with SMD, STMD's is allocated 25kgs of payloads for technology demonstrations on current CLPS mission manifests; this is approximately one-quarter of the 100kg payload space manifested by SMD on CLPS missions. Mr. Johns asked if STMD were investing in an ISRU Pilot Plant. Mr. Engelund confirmed that the directorate does have investments in it. Dr. Sowers asked if these capabilities show up in the architecture. Ms. Merancy said the capabilities show up as they become real. They don't go into the architecture until they pass an MCR, and can be linked to an objective. Dr. Sowers asked where a landing pad and sustained surface power belong in the

architecture. Ms. Merancy said M2M is still working to define those points and how they can be linked to the technology road maps. The need in the architecture is what the investments should be and are linked to. Mr. Reuters added that all the technologies under discussion are traceable to strategic plans and Moon and Mars objectives. Dr. Sowers said he would like to see more specific linkages in the briefings, to the general agreement of HEOC.

Mr. Engelund closed with a number of technology demonstration highlights: MOXIE on Mars, CAPSTONE, solar electric propulsion (SEP) thrusters for Gateway, cryogenic fluid management demonstrations (needed for both human and robotic exploration), successful deployment of LOFTID (ULA is using it now in reusable launches), and TeraByte Infrared Delivery (TBIRD). Mr. Hale asked if the ACR has identified anything that STMD is not doing. Ms. Merancy said it had not done so yet. Mr. Ebersole commented on STMD's pendulum swinging back and forth as a great way to find areas to pull. Mr. Hale felt the STMD strategy was very good for developing long-term requirements.

ISRU investments

Ms. Niki Werkheiser presented an overview on ISRU investments in STMD, describing how technology drives exploration by acting as the "tip of the spear" for incorporating technology when the opportunity arises. Key benefits of investing in ISRU include reductions in mission mass and cost; increases in safety; application benefits on Earth; and preserving the planet by responsibly using space resources. STMD, through the bigger picture of the Lunar Surface Innovation Initiative (LSII) is working its way to the Pilot Plant by concentrating on ice mining, an oxygen extraction ground demonstration, and data that will be acquired by the VIPER on the lunar surface. The Lunar Surface Innovation Consortium (LSIC), facilitated by Johns Hopkins Applied Physics Laboratory (APL), holds biannual general meetings, and monthly meetings on each of the six focus areas of ISRU, Dust Mitigation, Surface Power, Extreme Environments, Extreme Access, and Excavation/Construction. Each group has an APL lead, who provides feedback and recommendations to NASA.

ISRU Strategic Plan

Mr. Jerry Sanders presented details of the ISRU Strategic Plan, which had its roots in an STMD-led initiative called Go, Land, Live and Explore, which in turn was focused on identifying far future needs for exploration. The idea was to develop ISRU capabilities to produce commodities by starting small, and growing larger.. The ability to produce water and oxygen, and to extract metals, had to start with understanding what is available on the Moon, with an eye to supporting infrastructure, habitat construction, food production, and transportation components. ISRU involves any hardware or operation that harnesses and utilizes "in-situ" resources to create commodities for robotic and human exploration and space commercialization. ISRU can be thought of as a capability from prospecting to product, involving multiple disciplines. ISRU doesn't exist on its own— it needs a customer. ISRU requires power, needs to transported, and needs common navigation. ISRU can provide metals, feedstock for roads and structures. ISRU can also be thought of in terms of time and scale. The initial focus of ISRU will be on the south lunar pole, targeted on highland regolith and water/volatiles in permanently shadowed regions (PSRs); eventually it will evolve to more refined products and more specific minerals. As time goes on, ISRU focus on commodities like oxygen, water, hydrogen, silicon and ceramics.

M2M blueprint objectives and ISRU were released in September 2022 at the International Astronautical Congress (IAC). A significant number of blueprint objectives align with ISRU in three general areas (Resource Assessment, ISRU and Usage, and Responsible ISRU) and can be achieved with ISRU development and implementation. Initially, oxygen and water extraction were foci. Now that these areas have progressed, solicitations are moving forward to the next phase of work, in metal extraction and construction. Mars ISRU is being reevaluated as to where it will fit into the Mars architecture. MOXIE thus far is doing very well, and has worked under different conditions, but MOXIE is only 1/200 scale; ultimately, Mars exploration will need the production of 1-2 kilograms of oxygen per hour. NASA is funding this scale-up effort through SBIRs and Broad Agency Announcements (BAAs). Ms. Merancy added that NASA is looking at a whole suite of cases, some of which heavily include ISRU, to define the envelope to make decisions. Dr. Sowers asked how big a factor cost plays in trade studies. Ms. Merancy

said that affordability is a different assessment, which has been done for three propulsion systems. A cost assessment eventually be done for ISRU. Right now the focus on ISRU technology.

The ISRU plan to full implementation and commercialization will be achieved through CLPS missions. VIPER is the first ground truth mission for water ice; after that, NASA can determine what sort of ISRU mission will follow. The idea is to go with a pilot plant, an end-to-end demonstration, at a scale that buys down the risk of full-scale implementation. The scale has not yet been defined *per se*, but it is known that between 10 and 50 metric tons of O and fuel will be needed for some full-scale operations. One-tenth scale of that need is equivalent to one metric ton. NASA is leaving it open; the plan is to enable industry to be successful, and to promote industry-led activities. Forward plans for ISRU on Mars are to identify, characterize and quantify environments and resources for science and ISRU; demonstrate ISRU concepts, technologies and hardware applicable to Mars; and use the Moon for operational experience and mission validation for Mars.

Mr. Sanders described the biggest cost in terrestrial mining as the exploration phase, which typically takes a decade, with negative cash flow, and is followed by production. NASA needs to invest in the exploration phase to help buy down risk for industry exploration. Also, NASA can use challenges to garner university and public involvement. A meeting participant asked if Mr. Sanders was suggesting that STMD demonstrate where resources reside on Moon/Mars. Mr. Sanders said that mining language describes prospecting as "understanding the reserve potential;" the question is whether NASA use humans or robotics to prospect for resources. It is an open discussion. There is already a pretty good idea of what regolith is like, such that the ISRU Pilot Plant could be more a demonstration of the technology. VIPER is not heating the regolith. A pilot plant should have to demonstrate the ability to prospect a site, followed by the ability to extract resources. In response to a question about the structure of NASA Challenges, Mr. Sanders said that Centennial Challenges are open to anyone, and selections get phased into smaller pools of participants. Other Challenges are aimed at universities. Successful teams can eventually partner with companies, and Challenges can also seed future SBIRs.

Space Nuclear Capability Benefits

Dr. Anthony Calamino detailed the advantages that nuclear power can provide to space exploration: it provides a reliable energy source for both human and scientific exploration missions; offers energy -dense systems with high ratios of power to mass and volume; delivers continuous power autonomously for the extreme environments of space; and shares strong interest with commercial space and other government organizations. Nuclear capability also benefits the space leadership role of the US, the domestic economy, green energy, national posture, and global competitiveness. The fission surface power strategy at STMD is based on developing a 40kWe system that is scalable to higher power, with the aim of having a proven, launch-ready system for 2030. The system is currently in the technology development and formulation phase. Mr. Hale asked about the public safety requirements of such a system. Dr. Calomino said that the initial studies are design concepts that will inform requirements. STMD did pivot to the use of low-enriched uranium, which enabled broader industry engagement. Industry is already looking at launch regulatory requirements and safety, and the subsequent data will be rolled into Phase 2 efforts, which will become part of the statement of work (SOW). Mr. Hale noted that safety needed to be engineered in from the get-go and assumed that NASA would be doing this. Dr. Sowers noted that the devices under discussion are safer than Radioisotope Thermal Generators (RTGs). Dr. Calomino reiterated that the design is conceptual, and that the industry is acutely sensitive to safety. Ms. Budden said that "nuclear" is a loaded word for the public, and that NASA will require a press campaign to keep the issue from getting political. Dr. Calomino fully agreed.

Industry engagements have progressed well given the funding provided, and some participants are positioning themselves to engage with a lunar economy. NASA is executing three, one-year design contracts to produce preliminary point designs of a power system using industry design standards and practices. The aim is to provide subsystem TRL and maturity assessment, identify subsystem technology development needs, and provide cost and schedule estimates for system delivery. The three contracts are

with Intuitive Machines/X Energy, Westinghouse/Aerojet Rocketdyne, and Lockheed Martin/BWX Technologies. Industry designs are progressing well with a planned completion by September 2023 The final delivery products will be used to requirements for final flight hardware. NASA has using webinars to get information out to industry, and has also been having discussions with AFRL's Joint Energy Technology Supplying On-Orbit Nuclear (JETSON) power program managers.

STMD has recently started to look at nuclear propulsion in cis-lunar space; DoD is looking at cis-lunar space as well. Both agencies are very actively testing, and looking at launch regulatory requirements as well as issues associated with safety and public awareness. STMD is currently looking at sub-scale demonstrations for a nuclear thermal propulsion (NTP) system for cis-lunar space, and Nuclear Electric Propulsion (NEP) in the tens of kilowatt power range similar to the ARLF JETSON program. The experience gained with nuclear propulsion systems developed and deployed for cis-lunar space can be applied to Mars and potentially science missions. The Space Nuclear Propulsion Project completed three industry reactor design efforts in 2022 and continues to pursue fuel element fabrication demonstrations in FY23/24 with industry. STMD is also leaning forward in a partnership with the Defense Advanced Research Program Agency (DARPA), to to flight test NTP as early as 2027 under the Demonstration Rocket for Agile Cis-Lunar Operations (DRACO) program. NASA's ultimate goal is producing an operational nuclear system for cis-lunar space and potentially Mars human exploration. NASA is also continuing to work with the Air Force Research Laboratory (AFRL) on NEP technology needs, and has extensive working engagements with the Department of Energy (DOE).

The DRACO mission will not be operational; it will be a pathfinder, and also the first US nuclear fission system launched into space since SNAP 10A. Both DARPA and NASA are looking at High-Assay Low-Enriched Uranium (HALEU) fueled reactors that will eventually operate in the 2800-2900 degree Kelvin range. Recent reactor fuel testing has been successfully undertaken at the Transient Reactor Test (TREAT) Facility at Idaho National Laboratories. Testing has included a complete irradiation test series of a ceramic-ceramic (cercer) fuel form, and testing of uranium nitride fuel in a zirconium carbide matrix. To enable the DRACO flight demonstration, STMD redirected technology development project scope. Mr. Johns asked what STMD investments were wound down to rebalance the nuclear research portfolio. Dr. Calomino said that some reactor design activities were reduced, as was funding into nuclear fuels (with DOE), but STMD did get more funding overall. So far the budget impact of DRACO has been manageable. The DRACO demonstration is design offers an evolvable capability that can meet the requirements of a Mars exploration mission in the late 2030's. The demonstration vehicle will be launched to a nuclear safe orbit at least 1000 kilometers from Earth. For increase safety, when the fission reactor is packed for launch, the reactor will not have fission products, referred to as a 'cold reactor', and will be only activated once it reaches a safe orbit.

NASA and DARPA have an Interagency Agreement that defines roles and responsibilities in a jointly managed effort for the in-space flight demonstration. NASA will fund and manage the development, design, and test of the nuclear thermal propulsion engine, while DARPA will be responsible for funding and managing the development and design of the flight vehicle, assembly, integration and testing of the integrated system, launch of the demonstrator and in-space flight operations. The U.S. Space Force has issued a memo of commitment for launch vehicle and launch support, and the DOE/National Nuclear Security Administration will be providing HALEU fuel. The prime contractor is expected to be awarded in May 2023.

Dr. Calomino, in answer to a question, said that STMD has studied the use of thorium for lower power radioisotope applications as well as Americium. Asked about research into NEP, Dr. Calomino said NASA looks forward to working with AFRL on JETSON, if appropriate, but also has its own plans for an NEP demonstration in space. STMD has identified five integrated Critical Technology Elements (CTEs) for developing NEP systems, and is also looking at how to advance NEP at a subscale level for cis-lunar demos. STMD has completed a NEP Technology Maturation Plan (TMP), and the current FY23 investment of $1.3 M is being used to examine lithium-magnetoplasmadynamic (MPD) thruster testing,

Brayton PCS development, and NEP concept designs for cis-lunar space. Dr. Calomino felt that Brayton power systems would be key to high-power production. Mr. Johns asked if the DRACO mission would help to accelerate deployment of space nuclear propulsion. Dr. Calomino felt that a successful DRACO flight would accelerate the technology, but until the technology is tested in a relevant operational capability, there will be significant uncertainty. The demonstration will help STMD focus on a workable technology and eliminate unfruitful investment pathways. Mr. Hale said he was convinced that nuclear technology is an absolute requirement for both surface power and propulsion, and commended STMD for working hard with DARPA on the demonstration. His principal comment was: "safety safety safety," as well as issuing a reminder on public education. Ms. Budden mentioned the Strategic Capabilities Office (SCO) at DoD. SCO has the reputation of being a fast-moving organization with a talented and visionary staff, and a healthy budget. She suggested it would be worth describing what SCO does when briefing on nuclear technology research. Mr. Reuter commented that just making the fuel constituted a big development.

Public comment period

Sauli Kiviranta: Can you comment on the communication technologies needed to support surface operations, and how these mesh with the organization? Any thought to repair replacement approach, etc.? Mr. Hale said he would bring the question to NASA Headquarters (HQ).
Question: Will the meeting slides be available to the public? Yes. The presentations will be on the NAC websites.
Sauli Kiviranta: What are the non-hardware related aspects where mission success can be achieved. Is there hardware that can be replaced with software-based solutions? Mr. Hale said he would bring the question to HQ.
Scott Johnson: Long range radios need not be on every mission, if a dual stack IP/BP solution is implemented.
Emily Braswell: How assured can we be of mission success when it comes to things like human rated components being delivered by CLPS? Mr. Hale said he would pass the question along to the right person.
Robert Zimmerman: would worry about maintaining human situation awareness when it is necessary for humans to enter the operations loop; i.e. the situation awareness to transition from hardware in the loop to humans in the loop? Mr. Hale said he would pass the comment along.
AJ Khafari: Is NASA considering GenIV ideas for Thorium? Mr. Hale said he would take the comment to Dr. Calomino.
Question: Must the NEP flight demo be done along with AFRL or will NASA do it regardless?

Discussion

Mr. Hale briefly diverted from the discussion to congratulate the retiring Mr. Reuter on his stellar career.

Mr. Johns suggested issuing a joint HEOC/TI&E finding on the cis-lunar DRACO pivot. Mr. Hale agreed, and further suggested a joint finding endorsing DRACO. Ms. Budden added language to the effect that NASA is doing the right thing with the right people. Mr. Hale also supported an endorsement of the effort in surface power development. Mr. Johns concurred, and both Committees reached consensus. Mr. Voss asked how nuclear propulsion/power systems fit into the M2M objectives, and whether that should be mentioned in a finding. Mr. Reuter said the M2M objective should be available in the M2M documentation and can demonstrate how the finding is linked. Dr. Sowers suggested a general recommendation on technology infusion. He thought STMD had all the right stuff on their charts, but didn't see STMD research represented in the M2M architecture, showing that it indeed has a home in the future. He thought this should be made more visible in the STMD charts. He added that the middle two segments of the architecture elements is where STMD should show up. Ms. Michelle Munk said that STMD was working closely with segments beyond HLR, and that the leads are heavily integrated in helping to drive from top down into the characteristics, functions and use cases of technologies. As the impact of the technologies is analyzed, she felt that improvements in connectivity would appear in the ACR23. Mr. Hale agreed that there needs to be a more specific, explicit tie between the ACR and STMD.

Mr. Ebersole wanted to learn more about the communication of "shall statements" to industry: How do they take all that work and keep the discipline across the broad enterprise? What's the next step, how do you communicate needs into requirements that industry can respond to? Dr. Sanders concurred with these thoughts. A meeting participant commented that HEOC/TI&E findings on ISRU would be helpful in perhaps supercharging its development. Mr. Johns asked whether STMD should be looking at more specific uses for ISRU. Dr. Sowers reiterated his stance on extracting propellant from lunar resources as cost driver. Dr. Sanders noted that as soon as ISRU gets focused on tasks like metal extraction, the pool does shrink down to fewer providers. A meeting participant commented that ISRU is transformational; the hurdle is to get mission planners to see its value. Dr. Sowers agreed, adding that the forcing function for ISRU is putting it in the architecture. Right now NASA is totally dependent on a giant rocket, and a lander that has not been demonstrated.

Mr. Hale said that if both committees believe ISRU is transformational for the M2M campaign, it should state the case as a recommendation to the NASA Administrator accelerate ISRU. Ms. Budden commented that it NASA should make clear to the public that Artemis fabrication is important to the economy, as it is being supported by many small businesses all around the US. Mr. Hale suggested a HEOC finding on the the crucial role of small business in the aerospace economy. Dr. Sanders raised a data point, mentioned in the Moon to Mars presentation, of how much money comes back into the Treasury (3 to 1 ratio) from the Artemis program, as the basis for a possible finding.

Ms. Budden commented on the value of the joint meeting, and Mr. Hale said he would transmit this sentiment to the Chair of the NAC. Ms. Cline noted that when she had worked at NASA, there had been more competition than collaboration, and was delighted that this approach has changed.

May 16, 2023

Opening
Dr. Siegel opened the meeting and made administrative announcements. Mr. Hale recapped the previous day's events and findings discussion.

Space Operations Mission Directorate (SOMD)
Mr. Kenneth Bowersox, recently appointed as SOMD AA to replace Ms. Kathy Lueders, began the briefing by announcing an open Deputy AA slot for SOMD. He also mentioned the refinement of the ESDMD/SOMD reorganization as a recent significant undertaking, now completed. Displaying the previous organization chart, Mr. Bowersox highlighted a new group called Exploration Operations (intended to focus beyond LEO), to conduct operations for projects during the flight test phase, and a modified org chart with the Exploration Operations Office removed, and an added staff function in SOMD called Cross-Directorate Technical Integration (CDTI), attached to the Office of the SOMD AA, to help coordinate between SOMD and ESDMD. The work will remain in individual missions, while the CDTI will help make connections across the directorates to get the work done.

ISS

Currently there is consensus among NASA's international partners to commit to at least 2028 on Station; most have agreed to 2030. There is still additional discussion with the Russian ISS partners concerning activity in the 2028-30 timeframe. Meanwhile, ISS is busier than ever. ISS is working some technical issues but most operations are going well. The Russian Service Module still has a very small leak. ISS is tracking it and still trying to find the root cause. Dr. Condon asked what the situation would be if one or more partners decides not to go out to 2030. Mr. Bowersox said that there are some things NASA can work around and some it can't. That said, no one is in a mind set to walk away quickly; if such a thing were to happen, he expected that the team would work it out. Currently, SOMD is planning to purchase a de-orbit vehicle, and plans to store it until it is needed. Procurement is in process, and the hope is to have a selection by the end of the calendar year. ISS remains at the peak of its purpose. Much science is

being accomplished, and solar arrays are still being installed to provide continuing power. Cargo upmass and downmass transport is still a challenge.

Commercial spaceflight division

NASA's development of a LEO economy is ongoing. SOMD is now looking at a risk-based approach on flying crew, and innovating human spaceflight certification for the commercial sector. The division is getting close to a crewed flight with the Boeing Starliner. Asked why NASA needs a Suborbital Crew Program, Mr. Bowersox said the program could possibly be used for training, and for 2-3 minutes of microgravity for science purposes. Thus far, there is not a way to do this with government employees. NASA is learning from what commercial is doing, but has not yet identified an opportunity for astronauts (Federal government employees) to fly on commercial suborbital vehicles. If there were a regulatory regime in the manner of the Federal Aviation Administration (FAA), NASA might not need to do this separate certification effort. NASA is consulting Congress on lifting the moratorium on suborbital flight. Mr. Hale noted that the learning period expires in October of this year, while the FAA is already considering how they will provide regulation. It will be a roughly yearlong process to get a regulation into effect. These new regulations would also affect the private astronaut missions. Dr. Michael Lopez-Alegria asked how NASA gets around informed consent issues. Mr. Bowersox said that when NASA does the certification, it does not have to get informed consent for its employees to fly. Private astronaut missions, however, are not NASA-certified missions. Gets complicated. Without an integrated regulatory regime, NASA can't do some of the things that NASA and the space industry would like to see happen. NAS continues to work to find a way forward.

Space Communications and Navigation (SCaN)

Changes are under way in acquisition for relay services around the Moon. SCaN is establishing standards, and proposals are in for the commercialization effort. It should soon be possible to see if the financial/technical aspects of those proposals will meet NASA needs in cis-lunar space. Mr. Alibaruho asked if there were any new insights into the current state of maintenance and operability of the network. Mr. Bowersox said the space communications network has been constrained for funds for a long time, and consequently NASA has been looking at finding efficiencies, such working with the Follow the Sun effort (a type of global workflow in which issues can be handled by and passed between offices in different time zones, increasing responsiveness and reducing delays). With Artemis, NASA had to make heroic efforts to keep things working. The network also needs new antennae to support efforts in cis-lunar space. NASA needs to get money back into the maintenance budget. Dr. Sowers asked if Moon-to-Mars is part of the SOMD communications and navigation space. Mr. Bowersox affirmed this was so, and that SOMD has representatives on the Federated Board, is engaged in the Architecture effort, and is coordinated with ESDMD on the issues.

Human Spaceflight Capabilities Division

NASA is getting data from ISS to steadily buy down the risks on future exploration missions, and continues to develop countermeasures to the health risks of spaceflight and for the Moon to Mars architecture, and also is developing a strategy for commercial engagement to enable sharing of biomedical information

Launch Services Program/Launch Services Office

Mr. Bowersox noted that while many think of the Launch Services Program as merely "launching stuff for other folks," LSP is made up of hundreds of very specialized individuals who have expertise in launch vehicle (LVs). LSP serves as an important model for the Agency's transition to acquiring services for more day-to-day operations, while NASA itself operates out on the edge. LSP's most recent success was the launch of the TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats) satellite out of New Zealand, with a second launch following in the near future.

SOMD Budget

Ms. Elaine Slaugh gave a status of the FY24 PBR, while highlighting the SOMD goals of enabling sustained human exploration missions, and attracting and retaining a diverse workforce. The budget supports SOMD's overarching strategy of maintaining a safe and constant human presence in LEO, and operating ISS while continuing to develop a de-orbit plan. The FY24 PBR is $4.5B for 2024, up from $4.25B in 2023. The bulk of the FY24 increase is in the Crew and Cargo Program (services for commercial providers), SCaN, LSP, and the de-orbit vehicle, and in a movement of funds into construction and facilities for Deep Space Network (DSN) upgrades. In answer to a question, Ms. Slaugh said that launch vehicle purchases are done through the SMD mission lines. Mr. Voss said the budget from FY24-28 increases seemed to be not much more than inflation and insufficient for sustainable operations. Mr. Bowersox said that costs would be kept under control by switching to commercial services, and that as NASA plans for the post-ISS era, it wants to keep Cargo and Crew capability. Mr. Voss felt FY28 should be a much bigger number. Ms. Slaugh said to keep in mind that the outyears will change with future budget planning exercises, and that the de-orbit vehicle is in the Crew and Cargo line. Asked if SOMD anticipated issues, Mr. Bowersox said there had been a lot of support expressed for the de-orbit vehicle. Ms. Slaugh added that rocket propulsion tests come out of the infrastructure budget line.

The FY24 PBR manifest, out to the 2031 de-orbit, includes the design maturation phase of Commercial LEO Destinations (CLDs) and plans for LEO Free Flyers. ISS Operations and Management for FY24 includes the flight of many vehicles and working with international partners. ISS Research continues to benefit life on Earth through basic and applied research. Progress is being made in making experiments more efficient and smaller. ISS research us also benefiting climate research, and reaching 3 million students in STEM outreach. The ISS budget line amounts to a total of $1.3B; its principal risk is the current lack of a developed de-orbit vehicle. Ms. Slaugh reviewed the Space Transportation and Crew and Cargo budget charts. Dr. Sowers asked if the US was solely responsible for the de-orbit. Mr. Bowersox explained that the cost of de-orbit is based on mass on ISS. Because US mass is roughly 70% of ISS, that's what will be paid out through barter and services. The US will trade accumulated obligations with future obligations in working with Russia. The US will procure and operate the de-orbit vehicle. Mr. Bowersox went on to explain that multiple Progress vehicles was the original "plan A" for de-orbit. Ms. Robyn Gatens said the current solution is more robust than the previous plan to use multiple Progress vehicles, and that Russia will provide additional attitude/altitude services during the de-orbit.

Ms. Slaugh continued the briefing, citing no big changes in content in the Commercial Crew budget. Commercial LEO Development plans for FY24 is budgeted at $228.4M, to enable a sustained presence and U.S. leadership in LEO, and possibilities for a new LEO economy. A potential stressor for this budget is completion of development by 2028. In addition, the costs to procure CLD services and the costs to certify potential CLD crew transportation vehicles are not included in the submit; both areas will be re-evaluated during the next budget cycle. Asked about cost-sharing ratios for CLD, Ms. Slaugh said the ratios were similar to what is currently done in Commercial Crew and Cargo. She further elaborated on the cost share for the Space Act Agreements (SAAs) awarded for CLDs The program had an RTQ on this at the time of award to Blue Origin, Nanoracks, and Northrop Grumman. These funded SAA's represent a cost-share strategy where NASA and the awardee both contribute to the funding required to develop Commercial LEO Destinations. NASA encouraged bidders to maximize their financial contribution, and the private sector responded. The combined percentage of non-NASA investment proposed by the three awardees is slightly more than 60%, with NASA's contribution slightly below 40%. She further noted that Axiom is a FFP contract, so the question isn't really applicable to them, and she was not sure there was any way to figure out the Axiom contribution vs. the NASA contribution.

SCaN FY24 activities include four main areas: the Near-Space Network, Deep Space Network (DSN), Advanced Communication and Navigation Technology, and Spectrum Management. Mr. Alibaruho asked if SCaN had encountered any frequency issues tied to the other emerging spectrum users, and was curious as to how NASA views this problem, as the Agency turns to actively enabling the LEO economy and commercial space.

To support the Artemis program, SCaN is employing a Communications and Navigation 4 Point Support Plan, which entails upgrades to 34m DSN antennae, building a set of new 18m antennae, deploying a lunar relay and lunar interoperable network, and obtaining contributions from international partnerships. Ms. Budden asked if NASA had free access to NSF's global radiotelescope network. Ms. Slaugh did not know the answer. Mr. Hale suggested that HEOC have a briefing from SCaN. He added that he knew there was a concern that Artemis will oversubscribe the current space networks. Ms. Slaugh said she did know that Lessons Learned are being incorporated. Ms. Sue Chang from SCaN said she could look into the NSF question, noting that NASA is always looking into availability for redundancy and backup. She noted that the purpose of the 18m build is to help offload some science from the DSN, instead of using a requirement for a 34m antenna.

Ms. Slaugh displayed the overall FY24 SCaN budget of $579.7M, noting the risks posed by the dynamics of the Artemis program, and the FY24 Communications Services Program ($59.4M), noting risks posed by spectrum regulatory changes.

The FY24 budget for Human Space Flight Operations includes Crew Health and Safety, and maintenance of aircraft for training, is. Risks for this budget line is the aging T-38 fleet, which is being phased out. The SuperGuppy is also aging, and there is a risk associated with a need for additional crew. NASA has been having discussions with the USAF on the use of the T-7 aircraft. Mr. Hale mentioned that there has been talk about a need for helicopters. Asked if there were any requirements documents (for future aircraft), Ms. Slaugh said that a plan was in progress. Asked where lunar surface operations training resided, Ms. Slaugh said this training is covered by ESDMD, and by specific lunar programs.

The FY24 budget for the Launch Services Program is $103.8M, and provides funding for Liquid Oxygen (LOX)/methane studies, aimed at establishing risk of explosion from the newer LOX/methane rockets. Mr. Hale noted that the Eastern range is very concerned about it. Mr. Alihahuro said the industry is already using LOX/methane, and it looks like LSP is already contracting with them. Mr. Hale said there have been only two LOX/methane launches to date, and NASA would like to better understand the explosive potential. Ms. Tanya McNair commented that the studies are focused on trying to understand the risk in order to better prepare launch site mitigations, and that NASA is also working closely with providers to understand what they are doing. Asked when the study would be complete, Ms. McNair said that initial characterizations had been done, but she did not know the completion date. Asked if NASA was getting cooperation from other users of the Eastern Range, Ms. McNair affirmed this, and also confirmed that the Space Force (the largest consumer of Vulcan launches) is supporting the study too. Ms. Budden commented that it is never too late to invest in safety, as there will be plenty of future flights. Mr. Hale noted that the FAA looking at the Boca Chica area too.

The FY24 budget for the Rocket Propulsion Test (RPT) program is $48.6M. RPT provides state-of-the art testing for hypergolic and other fueled engines for Artemis, Commercial Crew, and other customers. No major content changes were noted. The FY24 for the Human Research Program is $153.5M, with no major content changes from the previous year. Ms. Slaugh provided a URL for the NASA budget website [[https://www.nasa.gov/news/budget]]. Asked how the budget was received on the Hill, Ms. Slaugh said she thought the discussions went well.

ISS

Ms. Robyn Gatens presented an update on ISS, which is in the midst of its "decade of results". Station is still enabling deep space exploration, with 23 tech demonstrations initiated since 2018, and 20 human health risks being burned down. ISS continues to foster commercial space industry, with over 500 payloads flown through the ISS National Lab, up to $1.8B of capital raised by start-ups post-flight, 20 In-Space Production Applications Awards to date, and one Private Astronaut Mission. In addition, research to benefit humanity continues, with 3400 investigations and 2500 scientific publications to date, (500 publications in top-tier journals), while Station inspires humankind, supports the economy (100,000 people at 500 contractor facilities); enables and expands international partnerships (111 countries/areas, recently flying the first UAE astronaut); and provides national human space flight infrastructure, with 22

years continuous presence in space. ISS remains heavily engaged in STEM, target students in K-12 and beyond, with activities ranging from Storytime in Space, to high-school-level robotics experiments, to having students operate EarthCam.

Increment 69 is very busy. ISS is getting ready for the launch of the Axiom-2 Private Astronaut Mission (PAM). The SpaceX CRS is launching on 3 June. The Boeing CFT is coming up, as are Dragon and Soyuz rotations. The current configuration includes a relocation of the Crew-6 Dragon to accommodate future vehicles. The UAE astronaut performed an EVA (representing a milestone) prepping a site for installation of new iROSA solar arrays. The EVA included an attempt to remove an antenna, but was stopped by a seized bolt, temporarily. Crew is about to install more solar arrays in sites that were prepared last year.

Significant items of interest include the atmosphere leak, which NASA continues to work with its Russian partners. Two cracks have been permanently repaired, strain gauges have been installed, but the root cause remains under investigation. Station is currently losing a little under 1lb per day (below the specification of 1.5lb per day). Asked about crack propagation, Ms. Gatens said the cracks have been stop-drilled, and subsequently put under monitoring. ISS is still using the module, which is very isolated and can be closed off with a hatch. Mr. Voss commented that Russians are less rigorous than NASA. Ms. Gatens said the situation had been thoroughly reviewed by both NASA and Russia, and that operationally, the hatch is left closed when there are no operations requiring it to be open.

NASA has released a draft RFP for the US Deorbit Vehicle, and expects comments from industry soon. The Agency hopes to award procurement at beginning of next calendar year. The vehicle needs to be onboard ISS a year before the de-orbit. The requirements are heavily based on present ISS visiting vehicles, thus it is not anticipated to be a completely new design. It will be designed to provide a big burn in a short amount of time so that ISS can be de-orbited over a target area. Dr. Condon asked if there is an estimate as to how much mass will be returned (for preservation) before de-orbit? Ms. Gatens said NASA is just starting to identify plans to bring down select items sooner rather than later. The Smithsonian Institution (SI) has requested a few items. Ms. Budden said that much goodwill can be established by offering items to museums other than SI; she suggested compiling a traveling road show (as had done with Apollo artifacts). Ms. Gatens agreed, noting that the general public has shown quite a bit of interest in ISS.

In other risk areas, ISS is still working the Soyuz 68/Progress 83 coolant leak. NASA has identified an emergency return scenario using Dragon for up to 7 crew members if this problem should happen again. In addition, science demand has been increasing for space on ISS. Station has established a new prioritization process, whereby sponsors will receive a minimum allocation of 70% of their request. The remaining 30% will be allocated based on a rotating order of sponsor (e.g. HRP, Tech Demo), which allows for each sponsor to plan for their highest priorities.

Utilization on ISS includes a number of exploration capabilities development technology demonstrations, including life support, environmental monitoring, and fire safety. The CapiSorb Visible System Investigation (FY23 hardware), a candidate liquid sorbent CO2 removal technology, has been completed.

ISS is using a new format for communicating science results. These are “one-pagers” comprised of an overview, results, impact in lay terms, icons representing scientific areas, and identification sponsors. For example, the Cold Atom Lab is described as the coldest place in the universe, a quantum science laboratory in Earth orbit, which creates a gel-like fifth state of matter called a Bose-Einstein Condensate, which has applications in quantum-based computing. Ms. Budden suggested adding, in layman’s terms, how these science results help in daily life. Ms. Gatens said the intent is to eventually have a, searchable repository of these one-pagers, acknowledging that the one-pagers could be further simplified. Committee members asked if the database would be made public. Ms. Gatens responded that eventually that is a possibility. Other one-pagers presented include How Gravity Guides Plant Growth, the AstroRad Vest, Using Worms to Study Muscle Strength in Space, and Effects of Microgravity on the Heart (using

microfluidic devices that mimic organ function), and Brine Processor Assembly Increases Water Recovery (a successful experiment that will feed forward to future missions). Ms. Stofan asked, in reference to M2M objectives, how this research goes forward as the commercial sector becomes more involved in ISS. Ms. Gatens said that NASA has been prioritizing these critical tech demos, which will also have the ability to fly on CLDs in the future. Asked about intellectual property (IP) issues between NASA and commercial providers, Ms. Gatens said it is a mixed bag. For instance, NASA owns the 4-bed carbon dioxide removal device and the IP, and some providers are using it; other subsystems are contractor-provided and they own the IP. Mr. Alibaruho commented that moving parts and corrosive chemistry are the problem for ECLSS; has NASA been able to increase the reliability of ECLSS? Ms. Gatens said ISS is still learning and testing, and reliability is a critical goal; it is better to ascertain the failure rate of a component to be able to anticipate problems and provide enough spares.

ISS external science instruments continue to accumulate; thus far Station has been able to extend missions for several instruments through re-location, while also adding more instruments. The latest climate instrument, Earth Surface Mineral Dust Source Investigation (EMIT), has produced initial results, in the form of cubes of wavelength data. EMIT can also measure methane emission sources. Asked about the Bigelow module, Ms. Gatens said that it was being used mostly for storage and some data collection. There are 282 science investigations on Increment 69, about the average number.

ISS National Lab has made it a priority to reach underserved communities, and continues its Education on Station initiative. Dr. Condon noted that StoryTime from Space is particularly well done, and asked if there was a way to gauge the student response. Ms. Gatens cited her own nephew's favorable reaction and said the intent is to collect more reactions. Mr. Ebersole said he had found that the 4th through 6th grade audience is a sweet spot, and recommended that NASA do more tracking after student engagement. Ms. Gatens agreed, and noted that ISS is considering offering internships to bolster workforce development. She noted that a new "Spot the Station" app will be coming soon.

ISS National Lab, (CASIS) met or exceeded target metrics in 2022, and underwent some personnel changes. CASIS is continuing to see more demand than resources available, and will be the recipient of increased CASIS funding, which will in part go toward high impact "Big Idea" awards in topics such as cancer research and tissue engineering. CASIS continues to see multiplier of funding ratio of 4:1. NASA is currently working on an action from National Space Council to develop a strategy for a future National Lab in LEO; there seems to be good public support for this idea.

An International Partner ISS Transition Working Group has been created to sort out what NASA and its international partners will do together post-ISS, and through what sort of cooperative mechanism. When NASA transitions to buying services, there will have to be a change from the current ISS barter system. The working group is developing "flexible science" concepts. Transition activities are under way in other areas ranging from de-orbit vehicle procurement to policy discussions. . An interagency working group established by the Office of Science and Technology Policy (OSTP) has issued a National LEO R&D Strategy that describes a "whole of government" approach to sustained LEO R&D. While agencies besides NASA do not yet have their own budgets for LEO R&D services, the vision is that in the future they will. The Office of Management and Budget is involved in the working group process. Dr. Sowers noted that many experiments on ISS have hidden costs that are borne by NASA, and wondered if participation would falter without NASA support. Ms. Gatens said that there are some calculations on the public site that will enable people to figure this out, adding that half of the ISS budget goes to transportation.

Commercial Programs

Mr. Alibaruho and Mr. Lopez-Alegria recused themselves from this discussion.
Mr. Phil McAlister presented an update on Commercial Programs, which is devoted to three primary activities: overseeing the Commercial Crew Program (CCP), Commercial LEO development, and Suborbital Crew. CCP flight accomplishments over the last 2.5 years have been characterized by a healthy and brisk cadence. In answer to a question, Mr. McAlister said NASA does some fleet following

on PAMs, though the Agency doesn't get involved beyond that. Major changes and accomplishments in the CCP are: SpaceX Crew-6 launched on March 2, 2023 and docked to ISS on March 3, 2023; SpaceX Crew-5 landed on March 12, 2023; the Boeing Crew Flight Test (CFT) is now scheduled to launch no earlier than (NET) July 21, 2023. The level of interaction between CCP and the Commercial LEO Program is becoming more robust and less stovepiped. Technical performance is good. Schedule performance has just improved from Yellow to Green, and it appears that a 6-month launch cadence for SpaceX is very doable. Cost performance has been excellent; Programmatic performance is also Green.

Crew-5 returned to Earth with no big items to report. Crew-6 launched in March for a 6-month stay, and Crew-7 readiness is proceeding on schedule, with the next launch planned for mid-August. The weekly scorecard review continues. The Boeing Crew Flight Test (CFT) is targeted to launch on an Atlas V rocket; certification products continue to be a pacing item for the test. The long pole is parachute verification. A parachute test is coming up in late June. The Boeing CFT will be a key flight. It will carry the first crew to land on land, and the first crew to launch from Cape Canaveral since the Apollo 7 mission. CCP contract cost performance has been excellent: the maximum value percentage growth average is 6.7%, which is under the CCP contract growth reporting metric of 15%.

In transitioning from ISS to a CLD environment, NASA would like to get the CLDs by the end of 2028, a very aggressive goal. The mitigation is that NASA has multiple partners, and will have to monitor the health of the Station as time progresses. NASA has four CLD partners now, which are a little more mature than the three Free Flyers, which are all making progress and making their milestones. NanoRacks has just added Airbus and re-baselined their milestones, and are now doing very well. CLD Phase 2 will be much like Commercial Crew. Phase 2 will begin the certification and provision of service phase. In response to a question, Mr. McAlister said that assuming they meet eligibility criteria, any company can bid in a full and open competition for a NASA award for a CLD. He noted that it has been good to see other companies entering the fray, which marks a very positive development for the overall market. Asked if any international partners had expressed an interest in developing their own CLDs, Mr. McAlister said he was not aware of any, but pointed out that the Chinese do have a CLD.

Commercial LEO Program accomplishments include the completion of over a dozen development milestones by CLD partners, the first Private Astronaut Mission (PAM), and the awarding of two SBIRs to commercial LEO companies. Mr. McAlister said he was pleased with these accomplishments, especially for such a complex program. FY23 was the second straight year of full funding, which more than doubled from FY22 ($102M to $224M). Dr. Sowers asked what the government/private investment in CLDs has been. Mr. McAlister said that in the case of Free Flyers, it is 60% private, 40% government. Dr. Condon asked if the business case analyses show that commercial companies can make a go of this. Mr. McAlister said there is no one business case, they are unique to each company. Nanoracks is very focused on science and research. Blue Origin is more focused on tourism. Northrop Grumman is concentrating on the government astronaut market. Axiom is looking at a number of markets. One key difference from Commercial Crew is that all of the partners are going to need non-NASA business to close their own business cases for an orbital destination.

Upcoming milestones for Commercial LEO include the release of a draft set of CLD requirements, hopefully by the end of summer 2023. NASA is still working on refining the CLD certification strategy. The Office of Science and Technology Policy is leading a study of CLD insurance and liability options (a potential showstopper, in the view of many). NASA hopes to soon award a second round of Collaborations for Commercial Space Capabilities (CCSC-2) no-exchange-of-fund agreements. International partnerships in post-ISS LEO recently benefited from some key NASA policy decisions; importantly, NASA has announced it does not intend to provide flight opportunities to foreign governments or space agencies for the provision of CLD infrastructure. Mr. McAlister thought this was a good policy clarification, and thought it was consistent with how CLD providers would like to proceed as well.

For the Suborbital Crew Program (SubC), NASA is assessing Blue Origin and Virgin Galactic using a

"safety case" approach, which is to assess the partner's overall safety processes using industry tools such as Probabilistic Risk Analyses (PRAs). The Agency is still gathering data. SubC is leveraging the experience of Commercial Crew and the flight worthiness process at the Armstrong Flight Research Center. Right now, NASA is doing deep dives on Blue Origin's escape, propulsion and parachute systems. For Virgin Galactic, NASA is studying the propulsion system, and mechanisms and operations. Mr. McAlister thought NASA could complete the assessment of these two providers by first quarter of 2024.

Challenges to Commercial LEO remain: ensuring continuing to fly safely, and ensuring there is no gap in US presence in LEO. Both CLDs and Suborbital Crew represent significant changes in the way NASA does business. The Agency's embrace of less traditional development strategies for CLD and SubC, while welcome, does bring its own risks. Mr. McAlister felt that NASA will have to have to learn to "let go" as the LEO market evolves.

Mr. Hale commended Mr. McAlister and NASA on standing up an innovative program.

Human Research Program

Mr. David Baumann reviewed the mission statement of the Human Research Program (HRP), which is devoted to reducing human system risks for exploration missions. The feedback loop for this process is through the Human System Risk Board. Risk ratings are Red, Yellow and Green. The five hazards of spaceflight assessed in the HRP are: isolation and confinement, distance from Earth, radiation environment; transitions between different gravity environments; and hostile close environment. These hazards are decomposed into human system risks (dust exposure, bone loss, circadian rhythm, etc.). HRP manages and monitors risk reduction activities for the different exploration design reference missions. As an example, a generic lunar design reference missions contain some Red risks (such as sensorimotor alterations). For a generic Mars mission, there are many more Red risks. These 28 human system risks require mitigations. For each one, HRP must put together a science strategy. Mr. Voss felt that overall, the risk chart minimized radiation risk.

HRP is located in SOMD, under the Human Spaceflight Capabilities Division, where it has interfaces with many different programs and offices, including the different Artemis Programs and the Mars Campaign Office. The HRP "Steps to Mars" are phased through three areas: Earth, Low Earth orbit, and lunar missions. The Steps to Mars approach uses many different research and operations steps to get to Mars. On Earth, research is comprised largely of spaceflight analogues that focus on individual hazards. In LEO, research on ISS will include the use of PAMs and future FF missions. HRP has research plans in place for Artemis missions II-V, including activities on Gateway. HRP is a nationwide research program, spanning 26 states and five NASA Centers. In addition, HRP conducts the high risk/high reward portfolio of its work through the Translational Research Institute for Space Health (TRISH), a cooperative agreement, with a consortium led by the Baylor College of Medicine. HRP is committed to Diversity, Equity, Inclusion, and Accessibility (DEIA) efforts, and is using dual anonymous proposal review (DAPR) for the first time to help mitigate unconscious bias, hoping to see results soon in new selections. Currently the number of Principal Investigators and co-Investigators, based on data from the Chief Scientist Office, are well represented among females. However, HRP is not getting a lot of applications from minority populations, and is now doing outreach in this area. TRISH is funding two diversity programs to this end, these are pilot programs that are starting to show progress. This year, HRP is also partnering with the Minority University Research and Education Project (MUREP), in a solicitation that will close at the end of May.

Mr. Baumann presented research highlights that represented progress on some selected risks. HRP has been studying likelihoods of inflight medical conditions, ocular changes and has started looking at individual variability in responses to spaceflightRadiation risk is still an area that HRP is studying to better inform crews and decision makers of the risks involved with Galactic Cosmic Radiation (GCR). NASA's Office of the Chief Health and Medical Officer (OCHMO) has established a new lifetime spaceflight exposure limit (600 milliSieverts), and has established design standards for shelters against

solar particle radiation events (SPEs). NASA now has a high-fidelity GCR simulator that will enable better characterization of GCRs in biological models,. The Agency has other mitigation tools available, such as flying crew during periods of solar maximum, and on shorter-duration missions. Research data is being made more actionable and available to partners such as the CLDs. Asked if restrictions associated crew privacy have been causing any backlog of available data, Dr. Baumann said there has been no hindrance in getting the data to the PIs and co-Is, but there is a lag for secondary users. Data accessibility is recognized as one of HRP's top program risks, and HRP has been putting resources into finding ways to allow greater and faster access to existing datasets.

FY22-FY23 analog missions made significant progress, including SIRIUS 21, an 8-month experiment that was successfully completed despite the intrusion of the war in Ukraine and the injury of a crew member. On ISS, human research studies occupy about 25% of crew time. Recent research includes rodent research that investigated the physiological effects of different gravity levels. TRISH laid groundwork for utilizing commercial spaceflight missions such as Axiom-1 and Axiom-2. Artemis/Mars enabling work is still planned for the ISS, including the CIPHER study, the most complex, integrated study ever of human physiology and psychology in space. There will also be a study of the ISS crews post- landing to evaluate their abilities to egress and and perform EVAs. HRP has also recently started a new genomic archive study..

HRP is working to enable near-term Artemis missions. Additionally, HRP recently worked with the larger Crew Health and Performance community at NASA to identify the top crew health and performance capability challenges for Mars. Currently, HRP is coordinating its work on areas such as a Mars food system across the different NASA HQ mission directorates. Joint roadmaps are used toidentify funding gaps, and coordinating schedules. HRP is also using collaborations with international partners. For example, NASA is helping to mentor the Indian space agency (ISRO), which is planning a human spaceflight program.To date, HRP has initiated partnerships with SpaceX to support their Polaris Dawn missions, and is already working with Axiom missions.
HRP and TRISH along with their commercial spaceflight partners have set the precedent that human research will be offered to all LEO commercial spaceflight participants. Looking to the future, HRP is working to ensure requirements will meet HRP and Agency needs for CLD partners. In response to a question, Mr. Baumann confirmed that NASA has an active relationship with the Air Force human performance wing. Mr. Hale expressed surprise at the change in how radiation risk is characterized. Dr. J.D. Polk, NASA Chief Health and Medical Officer, commented, saying that the Agency had made a conscious decision to use research investments from the terrestrial health care industry to understand and mitigate the future risk that radiation poses to crews. He said that cancer research over the last decade has produced new data, which NASA leveraged, and which led to a change in the characterization of radiation risk. Mr. Voss said he was not happy about the characterization of radiation risk. Dr. Polk said NASA had spent roughly $700M on radiation risk research over the last 15 years, and has also consulted other lanes of research. Mr. Voss felt NASA should just say that radiation is a major risk and accept it. He added that he felt there was no good answer to the problem, aside from accepting the risk and protecting against radiation events.

Dr. Steve Platts, the Chief Scientist for HRP, said that the program has not abandoned radiation. Radiation as a hazard is still being addressed by the HRP as it manifests in the carcinogenesis risk, and for its effects on the cardiovascular and central nervous systems effects; the latter two are more worrisome at present, and NASA is still spending roughly $25M a year on risk mitigation.

Chief Health and Medical Office

Dr. J.D. Polk described how NASA has been treating the astronaut corps over the years and how the approach to astronaut health has been changing. NASA recently published a list of conditions—"Find it Fix it Fly it"— that have been treated in the astronaut corps to date and returned to flight status. These data were once walled off but are now out in the open. As an example, six astronauts have been treated for atrial fibrillation by ablation, and successfully flew their missions afterwards. A different technique is used in astronauts that EVA qualified because of the risk of developing nitrogen bubbles in hypobaric

environments that could cross the atria of the heart; the procedure for astronauts was in fact refined by the doctor who invented the standard cryogenic cardiac ablation technique. NASA now aims to move from population health to personalized medicine for astronauts, which is based on one's unique risk factors, physiology, and genetic profile. However, the Genetic Information Nondiscrimination Act (GINA) prevents parsing astronaut genotypes for the purposes of mission assignment. The question here is whether NASA astronauts should be exempt from GINA, as are military personnel, for exploration missions. The military's exemption states that the mission outweighs the needs of the individual. It may be that there are genetic diseases that will disqualify a Mars astronaut. NASA wants to use genetic information not for qualification, but to tailor preventive regimes for astronauts. Advances in technologies and genetics have allowed sequencing for risk factors (BRACA1 and BRACA2) and have enhanced treatment platforms similar to mRNA vaccines that have promise in treating cancer by targeting only those genetically altered cancer cells. In addition, NASA is absolutely going to use Gateway and Moon as risk reduction platforms and proving grounds for Mars. However, Mars missions represent a different problem set. The question is whether 1/6 gravity environment is deemed enough to pull fluid away from eyes and perhaps prevent ocular problems associated with SANS, but transit to Mars in zero gravity remains an issue. Thus the ISS is a much needed platform to solve that risk. The other thing about Mars is it shifts the "life/limb/mission paradigm." Because crew can't get back to Earth in a timely manner, life or limb may have to be sacrificed for the mission, whereas in Low Earth Orbit, the mission is sacrificed for the benefit of the crew members.

Dr. Polk described the risks posed by long duration space flight and the fluid displacement that occurs in the body during microgravity. Spaceflight Associated Neuro-Ocular Syndrome (SANS)/Visual Impairment, Intracranial Pressure (VIIP) typically shows up after a few months. Each person has different degrees of symptoms which can change vision by up to 1 to 1.5 diopters. There is a fear that prolonged pressure might permanently alter the choroidal layer below the retina. The other significant concern is that increased intracranial pressure could potential cause brain injury, and cause cells to become inefficient at removing such things as tau proteins, which in turn might lead to an increased risk of Alzheimer's Disease. NASA needs to prioritize SANS, as this would not be a priority for other groups such as the NIH. . Thus NASA is "running out of runway" and has only 4 to 6 years to find a drug to mitigate this risk depending on the lift of the ISS platform. There is a clinical researcher in the United Kingdom who has been studying intracranial pressure for a totally different reason; this researcher is now studying astronauts to see if the drug can help. In other cases, medications can be flown to orbit, as in the case of an astronaut who was treated for a thrombosis of the internal jugular vein. As a result of this case, on-orbit astronauts now are checked for the presence of Protein C and S, and Factor V Leiden, all clotting factors. But this again shows the need for personalized medicine based on the personal risk that an astronaut might have. Another mitigation in work is optimizing function: treating the neurovestibular system or providing feedback in order to prevent nystagmus or saccades.. This affects vision and informs human factors design of displays- which in turn shows the importance of the integration of the health and medical technical authority in design process.

Bone loss remains a risk factor. However, there is a difference between bone density and strength; the cortical bone at the periphery comes back, but the trabeculum, the internal netting of the bone structure, thins out in space. Muscle changes too; there is an increase in the number of Type II fast-twitch fibers, which requires targeted exercise for mitigation. NASA can't send a massive exercise machine to Mars, as it does for ISS. Countermeasures will have to be changed. NASA has also been working with ESA to enable the flight of a para-astronaut. Amputees can suffer from skin breakdown and shrinking of the extremity (which can also occur in spaceflight) thus NASA consulted with a prosthetics expert who created a prosthetic with a mechanism that sucks the limb back into the prosthetic, and also created different sizes of sleeves to allow a better fit of the prosthetic for different conditions, such as to accommodate expected shrinkage, or EVAs. NASA has also been involved in contingency preparation and has visited different hospital ships and trauma facilities across the globe that might end up as a receiver in an abort scenario. The Agency also did a deep dive into Apollo mishaps. Despite the many years of history, there are still lessons being learned from those mishaps that help inform the standards and requirements put forward in designs for current spacecraft. During the Apollo 1 incident, the crew

died of carbon monoxide (CO) poisoning, as the pressure inside the cabin exceeded 30 psi, which caused the CO to permeate very rapidly. Activated charcoal (in the cabin filters) was the biggest source of CO; this finding resulted in a great number of lessons learned and mitigations to prevent such accidents in future spacecraft.

Looking forward, NASA is now working with the FDA and universities to research the capability to3D print medications. Dr. Polk also expressed a concern about the training and lack of aerospace board certification of practitioners in the commercial/private arena, and said NASA will try to influence this area through further studies in order to maintain the quality and specific space medicine expertise. In the meantime, NASA is practicing transparency and educating commercial and private entities on NASA's Lessons Learned. The Office of the Chief Health and Medical Officer believes they are ethically obligated to educate medical personnel in this area. NASA is also working with the National Medical Examiners Association, to train doctors to respond to mishaps, and to make more data available to the public. Dr. Polk said the OCHMO has received inquiries from insurance companies on the risks of space flight. NASA partners with DoD and the Federal Aviation Administration as it designs or develops new policies, and also has a trilateral board with FAA and DoD. A recent discussion has arisen as to whether should NASA start a registry for spaceflight, similar to firefighter registries. NASA is bound not by HIPAA, but by the Privacy Act, thus NASA is working to anonymize data for use in a future registry that may help inform the industry more broadly about the health risks for human spaceflight.

Public Comments

Gene Mikulka: Is industry helping to foot the bill on LOX/Methane studies? Mr. Hale said he didn't know and would try to find out.
Sally invite broader representation from software to simplify mission planning- HDTN? Hale- thank you for comment
David Huntsman: If the second commercial crew opts not to participate, does IP go back to NASA? Hale- don't' know, will ask.

Discussion

Mr. Hale applauded Dr. Polk's transparency and introduced the general discussion. He reiterated the need for a SCaN briefing, and noted that the NAC would be meeting in early July. Mr. Hale proposed another HEOC meeting in the Fall, perhaps another face-to-face meeting at a human space flight Center. Mr. Alibaruho thought that the quality of all the briefings were framed in a way that invited meaningful discussion and recommendations. Mr. Ebersole, Ms. Budden, and Ms. Cline agreed that in-person meetings are preferable. Mr. Voss suggested Mr. Hale touch base with the ESDMD and SOMD AAs to see if they have any extra concerns or recommended topics. Hale- point well taken.

HEOC reviewed draft findings and recommendations, beginning with a draft recommendation to the AA regarding Lunar Lander Services. Dr. Sowers advised an expansion to recommend that NASA do its own independent (of the supplier) risk assessment. Mr. Hale thought that NASA was already doing that, but that the question is whether they have the right insight. Ms. Cline suggested NASA seek insight into detailed schedule plans from lunar lander services, because NASA doesn't advise commercial providers directly. Mr. Alihaburo suggested NASA should "request" such insights.

HEOC discussed Ms. Cline's finding entitled: Endorsing the Agency-wide approach to the Moon-Mars Architecture.

HEOC discussed Mr. Ebersole's finding and recommendation, similar to Ms. Clines. Mr. Ebersole and Ms. Cline combined efforts on edits. Ms. Budden felt the recommendation should contain language to the effect that Moon/Mars planning should maintain its momentum through any change in administration.

HEOC discussed two recommendations from Dr. Sowers: Technology Infusion into the Moon Mars Program; and Acceleration of the Development of ISRU Technologies, as well as findings on a Commercial LEO Gap, and Risk Management. Dr. Sowers said his biggest concern about risk

management was identification of who owns it, and that the meeting briefers seemed to avoid saying SE&I owns and executes risk management. Dr. Sowers said he wanted to see this reflected at the Moon/Mars program level. Mr. Hale put this up as a topic for the next meeting, and tabled the finding.

HEOC discussed Mr. Alibaruho's recommendation, Strengthen Requirements for Material Logistics in Exploration Systems Architecture. Mr. Hale accepted the recommendation on behalf of HEO. Mr. Lopez-Alegria raised an issue about the lunar lander and in-flight fueling, asking if there were off-ramps if an opportunity was delayed. Mr. Hale said clearly the issue has been considered, and it is just not ready for prime time. Dr. Siegel thanked the JSC and support staff and Ms. Eracenia Kennedy. Ms. Budden noted that it was Dr. Siegel's last meeting as Executive Secretary and thanked her for her service. Dr. Siegel adjourned the meeting at 4:02pm.

Findings and Recommendations:

NAC TI&E and HEO Committee Findings and Recommendations:

Finding:
The two Committees commend STMD for their efforts in forming a Nuclear Thermal Propulsion (NTP) partnership around the DARPA DRACO mission. The Committees believe DARPA and NASA's roles and responsibilities as a part of the interagency agreement are appropriate and well-constructed. Nuclear propulsion will be critical to future human Mars missions, science missions to the outer planets and future cis-lunar operations.

Finding:
The two Committees strongly believe the Agency and stakeholders should prioritize Fission Surface Power (FSP) funding and development to support lunar exploration and a sustainable commercial lunar economy.

Recommendations from joint meeting with TIE committee

Short Title of Recommendation: Technology Infusion into the Moon Mars Program

Recommendation:
Clearly identify infusion path for technologies currently in development by STMD into the Moon and Mars Program architecture. Identify Lunar Surface capabilities, in particular In-Situ Resource Utilization (ISRU) capabilities within the lunar segments of the architecture. Conduct an architecture concept review focused on long term lunar presence and sustainability.

Major Reasons for the Recommendation:
The Lunar Surface Innovation Initiative is making great progress in maturing technologies to provide critical lunar surface capabilities. These capabilities are not currently evident within the segments of the Moon Mars Architecture. Identifying these capabilities in the architecture will provide a pull to ensure the technologies can be brought to fruition.

Consequences of No Action on the Recommendation:
Critical technologies may not be completed resulting in loss of capability and/or increased cost for Moon Mars missions.

Findings and Recommendations from the HEO committee meeting:

Title: Endorsement of the Agency-Wide Approach to the Moon to Mars Architecture

Recommendation: The Committee acknowledges and applauds the effort taken in the development of the Moon-to-Mars Architecture. Ensuring alignment across all the Mission Directorates, engaging a broad community for input and establishing an iterative process is a sound approach.

As written, the Moon-to-Mars Architecture Definition Document clearly embraces its purpose to translate the broad objectives into functions and use cases that can be allocated to executable programs and projects. The Committee embraces the effort as a best practice that will serve the program well as it allocates available funds into prioritized programs and projects. The Committee recommends the Architecture Definition Document serve as a consistent guidepost for development of "Shall Statements"for follow-on contracted activity with industry partners.

Major Reason for Recommendation:

To ensure the efficient application of the value of the Architecture Definition Document when contracting with industry partners to minimize program risk and any potential of requirements shortfalls.

Consequences of No Action on the Recommendation:

If the Architecture Definition Document is not applied consistently going forward across all program participants, the program risks losing important linkages throughout the program which could result in inefficient implementation, costly engineering change proposals, and schedule disconnects.

Short Title of Recommendation: Strengthen Requirements for Material Logistics in Exploration Systems Architecture

Recommendation: Perform more detailed assessment of design reference missions for Moon & Mars with specific focus on transport, stowage, inventory management, and conveyance of material.

Major Reasons for the Recommendation: In recent human space programs, cargo stowage and inventory management was a significant challenge that provided major headwinds to the programs' ability to use the platforms for science or other operations. It is advisable to give significant attention to logistics in the initial architecture up front so that science activity and other operations can be maximized and more efficient.

Consequences of No Action on the Recommendation: The Exploration Systems Architecture may focus on the conveyance of humans to and from the Moon & Mars without adequate treatment of conveyance of material that they need for their work.

Recommendation: Lunar Lander Services suppliers should provide detailed schedule plans to NASA and complete risk assessment to NASA.

Major Reason for the Recommendation: Apollo history shows that development of a Lunar Lander will be the pacing item for human mission to the moon. The Artemis Campaign is designated to fit inside a budget and schedule constraint. Without accurate planning for schedules and proper risk understanding accurate planning and maintaining schedules is not possible.

Consequence Of No Action:
If not implemented, the Artemis program will have significant cost overruns and missions will not be planned most effectively.

Short Title of Finding: Commercial LEO gap

Finding: It is extremely important not to have a gap in US LEO presence. Ensuring no gap requires close monitoring of the progress of the CLDs in relation to the planned 2030 deorbit date of the ISS and careful planning of the transition.

Appendix A
Agenda

Monday, May 15, 2023

NAC HEO Committee Public Meeting – Exploration Systems Development Mission Directorate (ESDMD)

Central / EasternTimes

8:30-8:35 / 9:30-9:35	Opening	Dr. Bette Siegel/Mr. Wayne Hale
8:35-9:35 / 9:35-10:35	Status of ESDMD	Mr. Jim Free
9:35-10:50 / 10:35-11:50	Moon to Mars	Mr. Amit Kshatriya
10:50- 11:35 / 11:50-12:35	Strategy and Architecture	Ms. Cathy Koerner
11:35/12:35	Adjourn	
11:35-12:30 / 12:35-1:30	Lunch	

Joint TIE and HEO committee meeting

12:35-12:45 / 1:35-1:45	Opening	Dr. Bette Siegel/Mr. Mike Green Mr. Wayne Hale/Mr. Michael Johns
12:45-1:35 / 1:45-2:35	Transitioning and infusing technologies into Artemis Missions	Mr. Walt Engelund Ms. Nujoud Merancy
1:35-2:20 / 2:35-3:20	Update on STMD ISRU investments	Ms. Niki Werkheiser
2:20-3:05 /3:20-4:05	Update on STMD Nuclear investments	Dr. Anthony Calomino
3:05-3:10 /4:05-4:10	Public Comments	
3:10-4:30 /4:10-5:30	Discussion and Recommendations	
4:30 / 5:30	Adjourn	

Tuesday, May 16, 2023

NAC HEO Committee Public Meeting – Space Operations Mission Directorate (SOMD)

Central /Eastern Times

8:00-8:05 /9:00-9:05	Opening	Dr. Bette Siegel/Mr. Wayne Hale
8:05-8:30 / 9:05-9:30	SOMD Status	Mr. Ken Bowersox
8:30-9:15 / 9:30-10:15	Budget	Ms. Elaine Slaugh
9:15-9:30 / 10:15-10:30	Break	
9:30-10:30 / 10:30-11:30	International Space Station update	Ms. Robyn Gatens
10:30-11:30 / 11:30-12;30	Commercial Space	Mr. Phil McAlister
11:30-12:30 / 12:30-1:30	Lunch	
12:30-1:30 / 1:30-2:20	Human Research Program Status	Mr. Dave Baumann
1:30-2:00 / 2:30-3:00	Office of Chief Health and Medical Officer	Dr. J.D. Polk
2:00-2:05 / 3:00-3:05	Public comments	
2:05-3:00/3:05-4:00	Discussion and Recommendations	
3:00/4:00	Adjourn	

Appendix B
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

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
Colorado School of Mines

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

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

Appendix C
Attendees

Human Exploration Operations Committee
N. Wayne Hale, Jr., *Chair*, NASA, ret.
Kwatsi Alibaruho, Industrial Sector Eaton
Nancy Ann Budden, Special Operations Technology, DoD
Lynn Cline, NASA HEOMD, ret.
Douglas Ebersole, former AFRL
Pat Condon, Aerospace Consultant
Michael Lopez-Alegria, Commercial Spaceflight Federation
James Voss, University of Colorado, Boulder
George Sowers, Colorado School of Mines
Ellen Stofan, Smithsonian Institution
Bette Siegel, Executive Secretary, NASA

Attendees
Patricia Sanders, *Chair,* Aerospace Safety Advisory Panel

Appendix D
List of Presentation Material

1. Exploration Systems Division Mission Directorate; *Jim Free*
2. Moon to Mars Status; *Amit Kshatriya, Lakiesha Hawkins, Steve Creech*
3. Strategy and Architecture Update; *Catherine Koerner*
4. Transitioning and Infusing Technologies into Artemis Missions; *Najoud Merancy, Walt Engelund*
5. STMD ISRU Investments Status; *Niki Werkheiser*
6. STMD Nuclear Investments Status; *Anthony Calomino*
7. Space Operations Mission Directorate Status; *Kenneth Bowersox*
8. Space Operations Mission Directorate Budget; *Elaine Slaugh*
9. International Space Station Status; *Robyn Gatens*
10. Commercial Spaceflight Division Status; *Phil McAlister*
11. Human Research Program Update; *Dave Baumann*
12. Office of Chief Health and Medical Officer Update; *J.D. Polk*

Appendix E

Chat Transcript

May 15, 2023

Can you comment on the communication technologies necessary to support surface operations, considering both equipment telemetry and human operator interactions and how those mesh with the organization? How are these technologies utilized to potentially decrease payload needs, for example, shifting from a 'repair by replacement' approach to 'deep-repair', thereby reducing payload requirements? Additionally, how do these technologies enhance the safety and productivity of the astronauts involved?
from Vincent (Ext) to Everyone: 11:47 AM
hellowill the ppt be available to public ? on ntrs or nac site on NASA.org
from Andrew Daga (Ext) to Everyone: 12:17 PM
Yes, I would like to be able to download all of the powerpoints used as well.
from Lynn Cline (Ext) to Everyone: 12:35 PM
No sound again
from Sauli Kiviranta, DCL (Ext) to Everyone: 2:38 PM
What are the non-HW related aspects where mission success can be achieved? It looks like there is plenty of emphasis on payloads, very natural, everyone loves physical artifacts and it is easy to procure physical artifacts. What are the top 3 process and more software related breakthroughs that are required for all of the missions to be successful or where we can automate/reduce costs or minimize payload requirements and drive cost down (in the spirit of software is eating the hardware). Even in a way what aspects of missions with physical artifacts are potentially replacable by software based solutions given certain breakthroughs?
from Scott Johnson (Ext) to Everyone: 2:41 PM
Long range radios need not be on every mission, if a dual stack IP/BP solution is implemented, Sauli. Similarly, lander mission clocks can be less robust with a Lunar local time server network providing IP based time updates from highly accurate time sources.
from Sauli Kiviranta, DCL (Ext) to Everyone: 2:42 PM
Thank you Scott, those are good examples
from Scott Johnson (Ext) to Everyone: 2:47 PM
I am fully in support of the idea of freeing up payload capacity with clever software deployment that eliminates the need for certain specialized hardware.
from Sauli Kiviranta, DCL (Ext) to Everyone: 2:52 PM
Ok, good, this would be aligned with how maritime/mining/energy sectors operate now. Plenty of their operational equipment have been moved towards software and reduce the complexity of equipment by using communication (iiot) to move certain operations and processing requirements away from the machines on the field to different parts of the overall architecture. Maybe not so much yet on the edge, but at least close proximity or even globally if the latency requirements allow. Just to give an example that if some equipment can be kept in orbit instead of being part of the rover we can simplify the landing requirements or ease requirements to help other parts of the system to reduce risks.
from Scott Johnson (Ext) to Everyone: 2:59 PM
That type of thing certainly becomes more robust as the number of landers and orbiters increases, with these devices having the store and forward capabilities to handle the data transfer aspects of these offloading operations.
from Sauli Kiviranta, DCL (Ext) to Everyone: 3:07 PM
That is a good point, also could help load balancing that less compute is needed collectively if tasks can be distributed when processing power is needed (e.g. if mission allows us to have 1 compute unit instead

of 2 once we can have better distributed system design). Also some operations may be technology constrained like cargo container handling, since we are dealing with human space exploration we may find opportunities in splitting the problematic tasks where automation is feasible and leaving some diffcult to automate parts for astronaut operators assuming that the data transmission infrastructure allows it, e.g. that operator could be in orbit or in habitat while there is a rover in operation. This may be more valid for expanding the scope of mission than simplifying existing plans though?
from Sauli Kiviranta, DCL (Ext) to Everyone: 3:26 PM
Maybe here we need in orbit high resolution gravity anomality analysis of the Moon since we are approachign from "space" direction like the ESA GOCE mission did for Earth? Instead of more classical mining industry approaches that are derived from terrestrial perspective. At least to minimize the search space for minerals.
from Emily Braswell (Ext) to Everyone: 4:06 PM
How assured can we be of mission success when it comes to things like human rated components being delivered by CLPS?
from Robert Zimmerman (Ext) to Everyone: 4:08 PM
would worry about maintinaing human situation awareness when it is necessary for humans to enter the operations loop. IE the situation awareness to transition from hardware in the loop to humans in the loop?
from Dr. Ajay P. Kothari (Ext) to Everyone: 4:08 PM
There are other Gen IV ideas, specifically using Thorium 232 which is quite safe that can be used as fuel for upper stage reactors or on Moon. Any comments?
from Emily Braswell (Ext) to Everyone: 4:12 PM
Is an NEP flight demo contingent on AFRL participation or will NASA pursue one regardless?
from Dr. Ajay P. Kothari (Ext) to Everyone: 4:16 PM
I mean Th232 (bred to U233) for fission. Not radioisotope.
from Ramish Zafar (Ext) to Everyone: 4:25 PM
Could you explain how cryofluid management is crucial for the Draco engine test
from Mitchell Walker (Ext) to Everyone: 4:31 PM
Congratulations!!!
from Sauli Kiviranta, DCL (Ext) to Everyone: 4:36 PM
Observer comment: What would be very good is to add more emphasis to the communications and impact of process improvements e.g. through advances in software side specially to mission planning. Lack of visibility and representation necessarily has the unfortunate after effect that missions will generally suffer from those aspects being more afterthought than integral part. This also in relation to adoption of latest standards such as Bundle Protocol across missions as well as across agencies and globally with partners and industries that participate in the missions. Great performance, safety and mission success benefits may be acquired through additional emphasis to software /comms / process changes.
from Sauli Kiviranta, DCL (Ext) to Everyone: 4:46 PM
As we are literally in the context of human space exploration, to bring the human-machine systems perspective and the human-in-the-loop part where most suitable or necessary for the mission to be success or where human-involvement even as a fallback system can improve the mission success. This in addition to the previous comment.

May 16, 2023
from Sauli Kiviranta, DCL (Ext) to Everyone: 8:28 AM

Yes

from Sauli Kiviranta, DCL (Ext) to Everyone: 8:29 AM

Yes all good!

from Sauli Kiviranta, DCL (Ext) to Everyone: 8:30 AM

Yes

from Eracenia Kennedy (Int) to Everyone: 8:31 AM

can one of you check your mic with us

from Heather D. Smith (Ext) to Everyone: 9:55 AM

I think it's ironic and also cool that they're so many former astronauts + flight directors in the room

from Sauli Kiviranta, DCL (Ext) to Everyone: 10:00 AM

That would be very very good!

from Gene Mikulka (Ext) to Everyone: 10:23 AM

For Public Comment Session: (Apologies for the early request but wanted to get this out there while it was still on my mind) On the LOX Methane Studies and thier impact of a potential explosion that could do damage to the launch pad and perhaps adjoining launch pads, Is the industry helping to fund that research? Is SpaceX, ULA, Blue Origin et cetera helping to foot the bill since it's their switch over to the LOX/Methane causing this in the first place? Thanks.

from Sauli Kiviranta, DCL (Ext) to Everyone: 11:15 AM

For Public Comment Session: As was mentioned earlier today (and briefly discussed yesterday), it would be great to invite broader representation from communications and to highlight the role of software and unified communication protocols. Progress in non-hardware aspects can significantly simplify mission planning and implementation, such as easing payload requirements and automating processes for requirements that overlap horizontally across missions, agencies, institutions, contractors, and suppliers. A prime example of this is HDTN, and it could be beneficial to involve them in future discussions:

https://www1.grc.nasa.gov/space/scan/acs/tech-studies/dtn/

from Heather D. Smith (Ext) to Everyone: 12:49 PM

Hi, Kim!

from Dave Huntsman (Ext) to Everyone: 3:26 PM

If the second Commercial Crew company, for its own corporate reasons, elects to NOT pursue providing operational commercial crew services to LEO after completion of initial NASA contract, does IP, technology, et al- like with Bigelow- fall back to NASA after the $B spent? And would NASA in that instance initiate search for a second CC provider? What’s the fallback plan? - Dave Huntsman