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Washington, DC**

**NASA ADVISORY COUNCIL
Human Exploration and Operations Committee
November 17 and 20, 2023**

MEETING MINUTES

Bette Siegel, Executive Secretary

N. Wayne Hale, Chair

**Public Meeting Minutes
Table of Contents**

Call to Order, Announcements	3
Status of ESDMD	3
Moon to Mars Status	4
Mars Campaign Office	6
Moon to Mars Architecture	7
Findings and Recommendations Discussion	9
Public Comment	9
Space Operations Mission Directorate	10
International Space Station	11
Commercial Space Division Programs	13
Commercial LEO	15
SCaN Status	16
Launch Services Program	17
Public Comment	18

Appendix A	Agenda
Appendix B	Council Membership
Appendix C	Meeting Attendees

*Meeting Report prepared by
Joan M. Zimmermann, T&J, Inc.*

November 17, 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 second HEOC meeting of the year. He noted several changes in the administration, first offering congratulations to Mr. Robert Cabana on his retirement, to Mr. James Free on stepping into Mr. Cabana's role as Deputy Associate NASA Administrator, and to Ms. Catherine Koerner, recently appointed as Associate Administrator for ESDMD. Mr. Hale announced he was stepping down from the HEOC, after having served as Chair for 4 years and 10 years serving on the NASA Advisory Council under three different Administrators.

Status of ESDMD

Mr. Jim Free updated the status of the Exploration Systems Development Mission Directorate (ESDMD), first expressing his gratitude to HEOC for their counsel, and thanking Mr. Cabana for his leadership and mentoring. Mr. Free was being replaced by Ms. Cathy Koerner, ESDMD's current Deputy Associate Administrator (DAA). He noted that Ms. Koerner has enjoyed an incredible career across many NASA programs, with experience as a Flight Director, as the Orion program manager, and as a propulsion systems engineer early in her career. Mr. Free thanked Mr. Hale for being such a valuable asset to the country, and to the NASA space program, and on behalf of his colleague Kenneth Bowersox (Space Operations Mission Directorate; SOMD) and himself, presented an appreciation plaque to Mr. Hale, recognizing his long and varied career from Space Shuttle days through to Orion. In essence, their sentiments were summed up as: "Thank you for being you."

Artemis II Progress

Mr. Free said there has been much discussion of the Orion heat shield, and the mission is continuing to work on it. The Mobile Launcher is at the pad while the team continues to process the vehicle. Mr. Free stated for the record that: "we are not going to fly until we are ready to fly." While Artemis II is still pressing forward with the hardware processing, if the team finds a reason to stop, they will stop. Everyone is acutely aware that there are four people going into the capsule, and no one takes this lightly. There is a good plan for the heat shield, and the team is executing to the plan and getting to the root cause. The crew is also going through training, and they are involved in every part of the hardware preparation. Core stage will ship early next year, and boosters are at Kennedy Space Center (KSC). Internal processes are being put into place. Limited life items are in the stack and protected, in response to the ongoing process of incorporating all the Lessons Learned from Artemis I. The crew escape system has been added to the Mobile Launcher, and water suppression and sound suppression paths are being assessed.

Artemis III Progress

As the mission makes progress on the Human Landing System (HLS), there are many questions, and many new items: new crew module, new suits, new lander. The Lander is absolutely important, but so are the suits, in that the Artemis missions are integrated missions. All the elements need to work, and one element is not more important than the others. The hardware is coming together, along with the European Space Agency (ESA) European Service Module (ESM), which is being built in Bremen (as are the other ESMs, all the way through to Artemis VI). Suits are working towards Preliminary Design Review (PDR), and Space X will be flying Orbital Flight Test-2 (OFT-2) on 18 November. The next big milestone for HLS will be the demonstration of tank to tank cryogenic transfer. Orion will dock with Starship, so the mission will have to look carefully at all the features and interfaces between elements. As Artemis continues to go forward, the Directorate continues to talk about all the years of work it has taken to make this all happen. The suit program completed its Design Verification and Testing (DVT) milestone, a big advancement in buying down risk. The data will be shared with NASA's suit contractors.

Artemis IV Progress

The Mobile Launcher for Artemis IV has a new sound suppression system; this is the pacing item for the mission, a significant job. The Exploration Upper Stage Structural Test Article has been built, and the Artemis IV Crew Module Pressure Vessel is at Michoud Assembly Facility; there is much hardware in flow.

Gateway Progress

Gateway components are under construction, including one of a kind hardware elements. The Habitation and Logistics Outpost Primary Structure Assembly is in progress, and the Power and Propulsion Element is testing a 12-kilowatt Solar Electric power unit.

HLS Progress

The development team continues to have regular interactions with both HLS vendors. The crew has provided critical feedback on the airlock and other interfaces via Virtual Reality evaluations. Preparations are under way for SpaceX's OFT-2 flight (within days of the HEOC meeting); NASA is looking forward to a successful test. The HLS provider for Artemis V, Blue Origin, is working through its certification baseline review. While NASA is buying these services, NASA technical teams remain an integral part of the effort. Selecting multiple vendors for HLS is great for NASA, increasing competition and innovation as we build a lunar economy with our partners. Mr. Free said he had visited the facility in Huntsville and viewed engine development for HLS and for other customers. Blue Origin is building a half-scale HLS mockup.

Mr. Free noted that budget stability would be helpful for the Artemis program and thanked the Mission Directorate for all the work it had to put in to deal with it. He expressed gratitude to the Program Managers (PMs) who wrote the justifications and planned for shutdowns.

Ms. Koerner briefly addressed the most recent internal Architecture Concept Review, noting that white papers and other products will be released at the end of January 2024, and that it was a

fantastic review. The program continues to architect from the right while mapping to the ultimate Agency objectives for Exploration. Mr. Free credited the whole of the Agency, factoring in Science Mission Directorate (SMD), Office of the Chief Financial Officer (OCFO), Office of the Chief Scientist (OCS), all of whom worked the strategy from objectives to requirements.

Discussion

Dr. George Sowers asked how much additional performance Artemis will get out of the new Exploration Upper Stage (EUS). Mr. Free said that the Interim Cryogenic Propulsion Stage (ICPS) line is now shut down, so for Artemis III NASA will have the third and final ICPS. He said he would get back to HEOC and follow up with the numbers, but that performance aside, the human rating will be the most important enhancement of EUS. Dr. Sowers noted that the Agency must have the EUS for Artemis IV, as there's no backup. Mr. Free confirmed this. He added that while the organization has undergone changes, the primary offices in the Moon to Mars effort are doing a tremendous job. New leadership has been put in place across the top and is functioning well. Mr. Hale congratulated the Agency on the selection of very well-qualified people.

Moon to Mars Program Office Status and Overview

Ms. Lakiesha Hawkins, Assistant Deputy AA for Moon to Mars, briefed the HEOC, first extending her gratitude and well wishes to Mr. Hale. The Congressionally mandated Moon to Mars program office is still in its infancy, but it has really picked up a head of steam on all fronts in terms of buy-in from NASA, industry, and international partners. The program is going to get increasingly complex, thus it will be critical to have an overarching organization. Most recently, the program held a series of team meetings and off-sites for both programs and industry, and has been communicating with internationals, looking back to Apollo, and embracing transparency in key schedule, cost, and technical risk parameters. The next task is to get integration offices up and running.

Artemis II mission status

As Artemis buys down risk from mission to mission, the program is conversing with technical authorities and crew going forward, incorporating Lessons Learned from Artemis I. Artemis II will offer the chance to do a lunar flyby, check out life support systems, perform a demonstration of crew recovery, and demonstrate proximity operations with ICPS and Orion. The launch is still scheduled for the end of 2024, and the program is evaluating risks to schedule. There has been a lot of great progress; the selected crew has unfettered access to the Moon to Mars program office. No issues are anticipated for the Space Launch System (SLS). The Mobile Launcher-1 (ML-1) refurbishment is on track and progressing well. Modifications to the ML-1 arm are nearing completion. The team is tracking to identify a tentative root cause resolution relating to the heat shield in late Spring 2024; the team is looking at some of the drivers, which include material properties that may have affected liberation; they are also looking at reentry trajectory, and they have done some crack-formation simulations.

Artemis III mission status

Artemis III represents greatly increased complexity in terms of traveling to a near-rectilinear halo orbit (NRHO), element pre-positioning, HLS, cryogenic fueling, tankers, and depots. Ms. Hawkins emphasized that science drives the lunar exploration rationale. A Geology Science

Team has been selected by SMD, and it is fully engaged with ESDMD as mission approaches are refined. The Artemis III Orion build is in progress, with continuing Service Module work in ESA's Bremen facility. The NASA Docking System (NDS Block 2) build is also in progress. SLS is going very well and is fully expected to be ready to go. There are no significant changes in Exploration Ground Systems (EGS). NASA Astronauts have been spending much time with the SpaceX team as HLS progresses. FAA licensing for the next orbital flight test is expected before the end of November 2023. Ms. Nancy Ann Budden asked for a list of the Geology Team; Dr. Siegel provided Ms. Budden with the list of team members. Ms. Budden responded and asked to have her response included for the record: *"Thanks for forwarding to the HEOC team the press release on Artemis 3 science and geology. This is a skilled, qualified, and balanced team of experts to support the Artemis science mission. In addition to some 'fresh faces' and talent, we are also glad to see a few members who have supported Lunar/Mars mission science for many years, who have participated in or led past planetary exploration, site selection, and science workshops. A great blend of capable people for the task ahead!"*

Mr. Hale asked where Artemis III will launch from. Ms. Hawkins said that launch pads will be used in Florida and potentially Texas. The missions will need quite a number of tankers; in order to meet the schedule, there will need to be a rapid succession of launches of fuel, requiring more than one site for launches on a 6-day rotation schedule, and multiples of launches. Mr. Hale commented that these requirements for sustainability and reusability will require a more complex architecture, so NASA needs to keep that messaging going to make sure everyone understands why this isn't Apollo 2.0. This point cannot be emphasized enough. Apollo was "one and done." This program is a long-term drive to move out into the Solar System with human exploration.

Artemis IV mission status

For Artemis IV, Gateway components (Power and Propulsion Element (PPE) and the Habitation and Logistics Outpost (HALO) will be added, and Orion will be docking with Gateway. This mission will feature a second demonstration of HLS with some longer-term capabilities. The crew will descend to the lunar surface, collect samples, return to Gateway, and then return to Earth. The mission team is actively talking about what is hard at each of these interfaces. These are direct conversations, and the team is having them often and early. Gateway will be in place about a year ahead of the mission. HLS is in progress and is meeting or exceeding NASA standards thus far. Mr. Hale said that meeting NASA standards is no small task and expected that SpaceX has had good experience going through the certifications for the Dragon vehicle. Ms. Hawkins agreed and said that everyone is on the same page in following a rigorous, well-documented process, from Level 1 requirements, up to the Agency level. Mr. Hale said he had toured the payload mockup and could understand why the I-Hab will be so important to the crew.

Artemis V

Artemis V will continue to build on the sustaining strategy, and at this step will be adding an additional provider for the HLS (Blue Origin). Blue Origin is moving through their standards adjudication, and then will move into a baseline review. NASA is confident that their design is on track to be successful. They have proposed some development work that will allow NASA to see what they are doing with HLS.

Mars Campaign Office

Ms. Hawkins briefed HEOC on recent accomplishments in the Mars Campaign Office (MCO), which serves as the bridge in the Moon to Mars framework. Currently, MCO is taking advantage of testing opportunities on the International Space Station which, in addition to Artemis, will help NASA get ready for Mars, concentrating on making the right investments and identifying critical risks. An Earth analog mission, Crew Health and Performance Exploration Analog (CHAPEA) is scheduled to complete in Summer 2024 and has been going very well. Ongoing topics important for going forward to Mars. Asked if in-situ resource utilization (ISRU) was part of the MCO purview, Ms. Hawkins answered that ISRU is definitely in the scope of MCO, and as the team matures, there will be more information about priorities for work on the surface of Mars. Dr. Sowers said he was encouraged by the current progress and had been briefed by Space Technology Mission Directorate (STMD) in May. Ms. Hawkins said that the office is now talking more about better aligning MCO with STMD and their resources, and that Ms. Dayna Ise is working that task. Mr. Hale and Ms. Hawkins agreed that Ms. Ise's work is exemplary.

Ms. Hawkins noted that MCO has heard the HEOC loud and clear on risk issues and was grateful for a strong Level 2 Integration Team, which is carrying out an assessment of the MCO risk approach. There was an acknowledgement and need to integrate risks in all of the programs, and to ensure risk mitigations are appropriately focused. Mr. Ebersole challenged MCO to look closely at the risk elements and split the process failures as well. He cited a Lesson Learned from the F-35 fighter program, in which a \$100 part on a fuel nozzle suffered from flaws in the manufacturing process of crimping hoses. This was a part that was susceptible to the human element; the challenge is to focus on process and understanding where the failure points are. He felt the Moon to Mars (M2M) structure was solid, but that the risk itself must be managed by the team culture. Ms. Hawkins said that when assessing the risk approach, Moon to Mars continues to execute to the risk assessment plan and procedural requirements, adding that the team has been charged with enforcing the culture of interrogating risk in every action. Risk awareness has to be infused into the approach, and the approach needs to be one that everyone can easily access. M2M recognizes this charge and is ensuring that each instance of risk is identified across interfaces and mission phases. Mr. Ebersole noted that M2M will need a comprehensive set of use cases to identify potential failures. Dr. Sowers said that it sounds like M2M is following prior risk processes and asked if HEOC could see some of those top risk products. Ms. Hawkins said the top risks include issues such as the heat shield, schedule concerns, mission challenges with Artemis III, and aggregation of fuel tankers. Dr. Sowers requested risk matrix displays. Ms. Hawkins said she would take an action to provide them.

Mr. Ebersole asked how industry participates in M2M. Ms. Hawkins said the approach was up and through the NASA program teams, but that the Agency is also engaging industry to see where the challenges are by having them present at quarterly program reviews, and talking with them in an open fashion, as much as possible. For major decisions, NASA brings in industry partners to support the discussions in program decisions. Dr. Pat Condon noted that assessing the risk matrix is a routine part of HEOC proceedings. Ms. Hawkins noted that M2M/MCO has a procedure that tracks risk across all six programs. Dr. Sowers said risk assessment would be a good topic for a dedicated HEOC session. Mr. Hale asked who in the program decides what risks need attention, and how the mitigation works. These are essential things to know. The Shuttle program had individual elements, but all the folks reported to an integrated risk management organization. Artemis is different because so many programs are contributing to the larger

endeavor. The Associate Administrator was the ultimate decision-maker. He said he looked forward to an in-depth discussion of how that works in M2M, at the next meeting. Mr. Hale continued, noting that in the Shuttle program, the AA concentrated on other issues while the Program Managers actually managed risk. M2M is a little different. Going across so many organizations, risk management really depends on culture. All of them will tell you they are doing risk management, but they have very different cultures, different definitions of risk, and how they make decisions can be very different as well. It will be difficult to nail this down for M2M, and HEOC will really have to go down to the working level and preach culture to them. In the Shuttle Return To Flight era, NASA went down to the bolt-turners at the factory; so HEOC will have to get out of DC and get on the ground. Mr. Ebersole noted that risk is realized at the “seams” and there are a lot of seams in this program. Ms. Hawkins said that M2M is working on heightened focus at interfaces, while also stepping back and looking at mission level risks. M2M marks the transition from individual element capabilities to integrated missions, and the mission will have to look at the seams more and more. Dr. Ellen Stofan echoed HEOC sentiments and requested risk reports at future meetings.

Around the Committee Observations

Mr. Hale asked for impressions “around the table.” Dr. Stofan said that with a lot of elements coming together, combined with high risk in an environment of uncertain budgets, M2M really must understand how priorities match the risk matrix. She said she was very concerned about budget instability and its impact on technical risks. Mr. Ebersole said that the scale of the Artemis program is overwhelming, and so many different components bring challenges to Program Management, and problems at the seams. Ms. Budden said that another layer of risk is the potential for organizational risk, and NASA must pay attention to this during transitions in leadership. Mr. Voss suggested prioritizing items that must be watched closely in the nearer-term missions. Mr. Alibaruho said he strongly resonated with the importance of budget stability, in that running large-scale technical programs, over numbers of years, must be planned carefully and with continuity. Ms. Cline echoed Dr. Stofan’s comments on prioritization as one way to deal with budget instability and felt the issue might be worthy of a specific recommendation.

Dr. Condon said that the roles and responsibilities between M2M, ESDMD, and SOMD were not clear, and that it would be helpful to get a good description of the three organizations and their interrelationships. Mr. Hale suggested a briefing on the subject at the next meeting. Dr. Patricia Sanders commented that they’ve made great strides in the last six months, but that one big challenge is that they will have to deal with legacy programs that are not well-synced; they now have a way to deal with it, which is encouraging. She was concerned about the amount of risk, however, based on the sheer number of “firsts” for Artemis III. Mr. Hale said that programmatic risk seems to be the number one risk, especially with regard to the budget situation. NASA needs to prepare for this, with a lot of plan B, C, D thinking. Organizational culture is also a risk, as it will take some time to ensure everyone is doing things the right way. He felt the architecture review at the Agency level was excellent.

Moon to Mars Architecture Update

Ms. Nujoud Merancy, representing the Strategy and Architecture Office (SAO) within ESDMD, briefed the HEOC. SAO defines the architecture for crewed exploration of the Moon and Mars, maintains the agency’s baseline exploration architecture, engages and integrates other

stakeholder input into the architecture, and guides applicable programs and projects through the pre-formulation phase.

SAO held their annual, internal Architecture Concept Review (ACR) at NASA's Kennedy Space Center in November. The ACR enables stakeholders across the agency to provide feedback on the Moon to Mars exploration roadmap. The 2023 ACR (ACR23) focused on refining sub-architectures, adding mature elements, and architectural strategies for the first crewed missions to Mars. ACR23 comprised two months' worth of internal review and was the second ACR in 10 months.

ESDMD will brief the NASA Executive Council about ACR23 in January 2024. After the Executive Council, NASA will publish the latest revision of the Architecture Definition Document (ADD) end of January 2024. This ADD revision follows the initial publication of ADD, which was released in April 2023.

ADD Revision A (ADD Rev-A) adds mature elements like the Pressurized Rover, Lunar Terrain Vehicle (LTV), and Gateway Airlock Module, as well as two elements from international partners: the Gateway Extra-vehicular Robotic System (GERS) from the Canadian Space Agency (CSA) and the European System Providing Refueling Infrastructure and Telecommunications (ESPIRIT) Refueling Module from the European Space Agency.

“Architecting from the right” involves decomposing characteristics and needs, use cases, and functions from NASA's Moon to Mars Objectives. NASA can then “execute from the left,” introducing elements that meet architectural needs by fulfilling those use cases and functions.

A model-based systems engineering (SE) toolset approach has been instantiated in ADD Rev-A. ADD Rev-A also contains a synopsis of the architecture decision process and a roadmap that describes the process for determining a logical flow of architectural decisions at a high level.

ADD Rev-A also includes refinements to the architecture segments and sub-architectures, and expanded decomposition of objectives into use cases and functions.

12 white papers will be published in January, elucidating key analyses and results of the 2023 ACR process. White paper authorship includes numerous NASA organizations and a portion of the topics resulted from discussions at the 2023 architecture workshops for industry, academia, and international partners.

2024 will be the first full-year cadence of the ACR process. The 2024 strategic analysis cycle will kick off in January, and will focus on next steps and coordinating communication, to prepare for a repeatable process as the architecture is revisited annually. The 2024 architecture workshops will be held in February to gather input from external stakeholders. The 2024 ACR will take place in November.

Moon to Mars efforts are multi-decadal, necessitating consistent and repeatable processes. Current process limitations for NASA include documentation that is not ideal for supporting repeatable processes (e.g., NPD 1000.5 and NPR 7120.5). Inconsistency in technical maturity

and mission expectations at formulation has led to issues for implementing programs that include cost, schedule, and risk.

To overcome these challenges, SAO has initiated a new pre-formulation process, element initiation (EI), as a new milestone and decision point. The EI functions as an overt integration point where a mission directorate commits to formulating an element that closes an identified architecture gap and is at an appropriate level of technological maturity.

Mr. Hale asked which milestones would require an Agency review (Moon to Mars objectives, Acquisition process, and MCR is conducted by the Mission Directorate). Mr. Voss asked where all the developments needed to go to Mars are documented: everything else is gaps and functions to be fulfilled—is this discussed in the ADD? In addition, is there a way to look at the far future items and put them on the timeline? Ms. Merancy noted that the ADD is not a budget request or a manifest. The team looks at the solutions. The ADD does not lay out a year-to-year manifest, but its concept analyses are meant to support budget request processes. Mr. Voss said that somebody has to be thinking about when to start new developments. Mr. Alibaruho asked about the acquisition strategy, as there has been an evolution in NASA's procurement approaches. Will NASA's acquisition process support these elements? Is there a risk that it will not? Ms. Merancy said that the ADD is trying to provide a thorough analysis and acquire the right data to clearly support an acquisition. Mr. Hale noted that STMD had partnered with DARPA on the Draco nuclear demonstration, and asked where such demonstrations in. Ms. Merancy said such elements come in at the Strategic Analysis part of the flow, where the pros and cons and trades are debated. That's where a downselect would be made. The pre-project teams will be matrixed at appropriate points in the process, which in turn will depend on the project being matured. Dr. Sowers asked for the distinction between mission and project requirements, saying he was hung up on system vs. missions. SLS is a system, while Orion is a mission. Dr. Condon asked where SOMD gets involved. Ms. Merancy said that SOMD is already involved, and SCA_N in particular, to identify common navigation needs and to determine what upgrades will be needed. SAO will work with SCA_N as they upgrade to support the evolving architecture. Mr. Hale provided some context about NPR7120.5 (the "NASA Constitution" on how to run a program or project. Ms. Merancy directed HEOC attention to nasa.gov/architecture, which includes data from the architecture workshops, and which will function as a living web page.

Discussion

Asked to define recurring tenets of the M2M architecture, Ms. Merancy cited safe crew return, international partnerships, responsible use of space, etc., which are applicable across the entire architecture and its objectives. In response to a question, Ms. Merancy said that ISRU will be covered well in Rev A. Mr. Voss asked what process decides when NASA will begin a budget allocation process, or the standing up of an office. Ms. Merancy said that the ESDMD AA has that responsibility of deciding when it's time to start such initiatives. Asked what the trigger points for making these long-range decisions, Ms. Merancy said that that is what SAO is working on, and that they will provide this information to the (ESDMD?) AA. Ms. Budden said that for the record, this sort of planning is often off-schedule with administrations, which is a perennial problem for such long-term objectives. Ms. Merancy commented that the physics of getting to Mars will not change, and that the architecture will at least will have all the necessary elements documented. Ms. Budden applauded the work of the SAO team and the clear graphics.

Mr. Hale said he could recall days of internecine squabbling and felt that building the team and assuring buy-in has been a worthwhile effort. Ms. Merancy said that SAO is talking weekly with Science and Exploration and is pleased with the level of communication.

Findings and Recommendations Discussion

HEOC discussed potential findings and recommendations. Ms. Budden applauded the progress shown by all the directorates, as well as the increased detail in presentations. Dr. Condon felt there should be an action item for the building of future agendas to include briefings on risk assessment. Dr. Siegel noted this topic would be on the next agenda. Mr. Hale said that chart production represents a long arduous process, and that HEOC members should be mindful of this when making a request. Dr. Sowers said the Artemis missions will need an enormous number of moving parts that need to be integrated seamlessly, and there is much risk associated with this. The Artemis Program needs SE&I at the Enterprise level. Mr. Hale said HEOC has requested this many times, and that there is someone at Marshall Space Flight Center (MSFC) who is the Enterprise integrator for Artemis; HEOC should ask how this office folds back into the M2M Office. Mr. Ebersole said it would be interesting to visualize the entire process. Dr. Sowers asked: How does it all come together for Artemis at the mission level? Mr. Hale noted that for Artemis I, a flight readiness process was presented to the AA. HEOC could probably obtain this process as a briefing, but future missions will be more complex. Dr. Sowers reiterated that he would like to see more SE&I (and risk management) at the Enterprise level. Mr. Hale said he would accept this as a finding, with general concurrence from the Committee. He said he also wished the flight charts would show how the HLS lander fits in (for both SpaceX and Blue Origin). Dr. Siegel took this as an action item, noting that some details might still be proprietary. Mr. Hale concurred, adding that cryogenic fuel transfer will be hugely valuable, but has never been demonstrated. It would be good to know how the technology is developing. Mr. Voss agreed, adding that the program needs to prioritize looking at the nearer term, and focus on those items in terms of remaining risks.

Public Comment Period

Ms. Emily Braswell directed a question to Mr. Free: What are NASA's success criteria for OFT-2, and how critical is it for the flight to succeed? Mr. Hale said he would pass the question to Mr. Free.

Mr. Chris Gilbert asked, in view of in-depth reports: shouldn't more specific corrective actions (as from OIG and GAO) be part of the advisory process? He also said a mission manifest chart had been omitted and asked why Mr. Free was not required to have these specifics. He added that NASA never mentions lunar surface campaigns, although they take years to prepare.

Mr. Robert Zimmerman said he would like to have seen more about timelines and risk management- the physics of getting to Mars won't change, but everything else will evolve over the next decades; he said he hoped to see much more attention paid to these critical items like human systems, planetary protection.

Mr. Gene Mikulka said he would like to hear more about political and budget risks, and how these could be mitigated.

Mr. Brian Harvey asked how HEOC felt about DARPA's lunar surface infrastructure. Mr. Hale said he was not very familiar with it. Dr. Sowers thought it was complementary and aligned with the current program.

Mr. Chris Gilbert asked if HEOC was familiar with the international space coordination committee, Global Space Exploration Roadmap. Mr. Hale said HEOC had had a briefing from them two years prior and thought the Roadmap had been superseded by the Artemis Accords and the SAO.

Discussion

Ms. Budden asked if the new AAs would be briefed on all the recent advisory findings and recommendations. Dr. Siegel said that Ms. Koerner is up to speed, but that the new Deputy will need to be briefed. Mr. Hale said that there will soon be two vacancies on the HEOC and proposed that the Committee be split into two to serve two AAs. He encouraged HEOC to have detailed discussions with the new people coming into their roles at both SOMD and ESDMD. Dr. Siegel thought that splitting the Committee will probably take a year. Ms. Cline suggested making a consolidated list of all the recommendations made by HEOC, especially for the relevant programs; this is good data for incoming staff, and it can serve as a refresher for HEOC. Asked what had happened to HEOC's May recommendations, Mr. Hale said the full NAC has been challenged by illness and other issues, preventing recent meetings. The recommendations will be presented to the full NAC when it reconvenes.

November 20, 2023

Dr. Siegel re-opened the meeting. Mr. Hale made brief remarks.

Space Operations Mission Directorate (SOMD)

Associate Administrator for Space Operations Mr. Kenneth Bowersox briefed the HEOC, first expressing his appreciation for Mr. Hale's service to HEOC and to NASA. Mr. Bowersox gave a high-level precis of the latest activities in SOMD. The Human Exploration and Operations Mission Directorate (HEOMD) is continuing its separation into two mission directorates, each trying to develop an identity. SOMD has five divisions with programs: Commercial Space, Space Communications and Navigation (SCaN), Human Spaceflight Capabilities, Launch Services, Human Research, and ISS; two that are cross-cutting: Strategic Integration & Management Division, and a cross-directorate technical integration group, which identifies where new ties need to be made between activities, and a Resources Management Office.

NASA astronaut Frank Rubio recently set a record for the longest continuous presence in space, at 371 days. His stay was not planned, but it was an event everyone was prepared for. Mr. Bowersox said he was proud of what Dr. Rubio and his crew accomplished. SpaceX's 29th commercial resupply mission was launched to ISS and included ILLUMA-T (Integrated LCRD Low Earth Orbit User Modem and Amplifier Terminal), an optical communications demonstration. This was a relay demonstration, which will help a lot in the next decade. In August, SOMD flew NASA's SpaceX Crew-7 mission to the ISS. Another private astronaut mission (PAM) selection has been announced by Axiom (AX-3), which will include HEOC member, Mr. Mike Lopez-Alegria. PAMs give NASA an opportunity to fly small cargo up to space station, and also keeps additional vehicles in the preparation flow for contingency situations. PAMs also help NASA learn about the private low Earth orbit market. The Psyche mission launched on a Falcon 9 in October and is on its way to visit a highly metallic asteroid. For communications, Psyche is also carrying an optical communications payload called Deep Space Optical Communications (DSOC), representing another important step for putting optical

communications links on additional missions. In the Launch Services Program (LSP), many similar agreements are being made with small launch providers, enabling higher-risk, lower cost testing of technologies. The Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats (TROPICS) launch was a case in point. The Earth analogue mission, Crew Health and Performance Exploration Analogue (CHAPEA) (which is led out of ESDMD, working with the Human Research Program), is under way, with four people in place for 378 days, in preparation for lengthy Mars missions.

SOMD challenges for the next year include how to transition plan the next 10 years in low Earth orbit, as commercial takes over; sustaining performance on all missions; how to handle communications in the Artemis era (new procurement approaches to acquire services, e.g.); and resource uncertainty.

Dr. Sowers asked how SOMD is involved with Starship. Will the Launch Services Program (LSP) be certifying them? Mr. Bowersox said there were some LSP folks supporting HLS, but that SOMD won't be adding Starship until they get further along, at which time LSP involvement will increase. SOMD is also supporting SpaceX through an unfunded Space Act Agreement (SAA). If SpaceX has a question, they can use the Commercial Crew programs. ESDMD has more ties with SpaceX at present. Mr. Hale said he was surprised that the latest SpaceX launch did not use SCaN. Mr. Bowersox said that SpaceX uses Starlink and ground-based stations whenever they can, but he thought they used some NASA Tracking and Data Relay Satellites (TDRS) during the last launch. Ms. Cline said there is new procurement for space communications to provide relay service at the Moon and also direct to Earth (DTE), and that there might be an announcement of providers in late 2023/early 2024. This is a flexible procurement with a table of services in cis-lunar Earth communications. Ms. Budden said she would be interested in learning what suit upgrades were devised for the AX-3 mission, which will use the newest space suits. Mr. Bowersox said he thought they're the same suits used on the Dragon. Axiom has a contract to develop the new space suits. The main goal of the suit evolution is to enable them to be used both in flight and to walk on the surface of another planet. Another major goal is to expand the range of sizes. Collins Aerospace is the other suit vendor. Ms. Budden noted that multipurpose suiting is a good cost-saving measure. Mr. Bowersox said the most expensive part of the suit is the life-support backpack, but that it provides good modularity. Dr. Siegel took the action of adding a review of spacesuit/EMU development as a topic for a meeting in early 2024.

International Space Station

Ms. Robyn Gatens gave an update on ISS, noting that 2023 marks the 25th anniversary of ISS's first element launch. The ISS supports a range of goals for the Agency and the nation, some of those goals and metrics are listed here. In support of a mission objective to enable deep space exploration, a total of 26 NASA technology demonstrations have been flown since 2018. In addition, ISS has characterized 20 human health risks and is continuing to develop countermeasures. ISS is also fostering the commercial space industry: of over 500 payloads flown, 75% have been from the commercial sector, representing \$1.8B of capital raised post-flight. There have been 20 in-space production applications awards to date, and two PAMs flown with another 2 in the planning phases. ISS continues to inspire humans all over the world, an effort that involves more than 100,000 people at 500 contractor facilities and has reached over 10

million students. Research to benefit humanity- more than 2000 international-led investigations to date. Enable international collaboration, up to 117 countries that have participated, also completed first increment with a UAE astronaut; providing a continuous infrastructure in LEO, 23 years of continuous human crew presence in space.

The current increment, Increment 70, is comprised of three Roscosmos, two NASA, one JAXA, and one ESA crew. Some of the newest instruments on board were launched on SpaceX 29, ILLUMA-T, an optical communications test, and the Atmospheric Waves Experiment. Increment 70 will feature multiple visiting vehicles for crew supplies and science, and a crew rotation in the Spring will close out the increment. The current ISS configuration includes the Crew-7 Dragon (arrived in August, leaving in February 2024); SpaceX 29 (docked November 11 and leaving in December); Cygnus at the nadir port (leaving in December 2023); one Soyuz (leaving March 2024); and two Progress vehicles. Roscosmos is planning EVAs for removal and replacement of components, inspections, and continued outfitting. The last Russian EVA was to inspect a leaking radiator system; the crew was able to isolate the coolant loop and the investigation and forward plans for operations are in work. On the US side for EVAs, crew completed two additional iROSA solar arrays installations; there are now six arrays for augmenting power, and two more to be installed in 2025. In upcoming EVAs the crew will reattempt to remove and bring inside ISS for return to earth a communications device as well as do a microbial survey. Asked if a recently lost toolkit poses risk to other satellites, Ms. Gatens said its trajectory indicates it will reenter the atmosphere safely. She said EVA toolkits are usually tethered as a matter of protocol, and the loss of the toolkit is an abnormal occurrence, and under investigation.

ISS continues to track an atmosphere leak, the result of small cracks in the aft section of the PrK portion of the Russian Service Module. The leak rate has increased slightly, while NASA and Roscosmos are investigating the cause. The current leak rate is one pound/day, still well below specifications. The hatch to the module has been closed when not required for operations or troubleshooting. Mr. Voss commented that a pressure vessel with cracks in it should be of big concern, as the closed-off vehicle presents an opportunity for catastrophic failure. Ms. Gatens said that a minimum pressure is being maintained in the compartment. NASA is aware of the potential for failure and has identified the worst-case scenario as loss of the port. No other areas of the ISS have seen these types of leaks and cracks. Mr. Hale directed that this topic be covered at the next meeting. Investigations into coolant leaks on Soyuz and Progress continue, as well as a leak in the MLM backup radiator, which was identified in October. In other activities, End of Life (EOL) de-orbit planning has been a major focus this year. NASA released a Request For Proposal in September; the aim is to award a de-orbit vehicle in Spring 2024.

ISS has hosted a number of Exploration Capabilities Development Technology Demonstrations in the areas of Life Support, Environmental Monitoring, and Fire Safety. A second Spacecraft Atmosphere Monitor (SAM) unit has been installed and has the ability to monitor trace gases. The SAFFIRE VI fire safety experiment has been delivered and will be initiated after Cygnus leaves ISS. Research highlights include the 3D printing of a human meniscus in space (Redwire), which has implications for both space and terrestrial regenerative medicine. A newly installed water dispenser has improved water sanitization on ISS, making it more resilient to microbial growth. ISS is also part of the White House Cancer Moonshot Initiative, a whole-of-government

approach to finding cures for cancer, as well as for enabling earlier detection. There is a “full house” of science instrumentation on the ISS exterior, representing multiple US agencies and internationals. Asked about the AMS upgrade, Ms. Gatens said that another tracking layer is planned to be added to AMS, which will allow a three-fold ability to detect cosmic rays, along with a cooling upgrade is scheduled for late in 2025. There are currently 189 investigations in the current increment.

Education on Station activities include Genes in Space; sponsorship of the Girl Scout Phenom Convention; Story Time from Space, and the addition of 81 new partners in the Space Station Ambassador Program. A new Spot the Station phone app has also been developed.

CASIS (ISS National Lab) is meeting FY23 metrics. Attrition of staff has tapered off and CASIS has the staffing needed to conduct the objectives of the team. Demand has been exceeding resources; the pipeline is full, and CASIS is trying to prioritize the most impactful activities. Ms. Gatens felt this boded well for commercial space. Earlier this year, NASA held a successful ISS Research and Development Conference in Seattle, attracting nearly 1000 attendees. ISS is continuing to work on a formal action from the National Space Council to develop a strategy for a future National Lab in LEO, and also hosted a federal workshop to explore future plans for LEO. The workshop featured over 100 attendees and engendered lots of energy for collaboration and resulted in the establishment of some micro-working groups in specific areas.

NASA continues to put more definition into future plans for the transition of LEO to commercial vendors. The goal is continuity of human presence in LEO. NASA aims to be one of many customers in commercial space and is looking for common objectives with the current international partnership in ISS. Destinations are being added to the Commercial Crew and Cargo programs to expand commercial LEO. NASA wants to use these platforms to help meet Moon to Mars objectives, and to continue to inspire humankind. The latest transition activities include issuance of a Request for Information (RFI) with an initial description of NASA needs. NASA is currently getting feedback from potential commercial providers and taking that data and turning it into initial requirements. ISS EOL planning is fully underway. The National Space Council is chairing a committee on regulatory matters associated with EOL and is developing ideas on how to transition in a way that allows international agencies to continue to work with NASA. An ISS International Partner Transition Working Group has also been formed. The major challenge of the transition is to prevent gaps in LEO. Before eventual deorbit of the ISS the Agency needs to safe a safe way to bring ISS down into earth atmosphere for destructive reentry as well as have operational commercial LEO destinations operational to avoid a gap.

Mr. Hale noted that under the Outer Space Treaty, governments normally supervise government-owned space assets; Does this mean commercial space stations will fall under FAA jurisdiction? Ms. Gatens said that monitoring Commercial Low Earth Orbit Destinations (CLDs) is definitely a gap in the framework; orbital assets could fall under FAA or the Department of Commerce. Mr. Phil McAlister said that an interagency Working Group has proposed a policy for FAA, as well as the FCC, which has some authority over nonhuman space flight. This will be a Congressional decision. NASA has been having ongoing meetings with FAA to help them digest Lessons Learned. There are still a lot of unknowns, but NASA is making progress on closing the regulatory gaps.

Dr. Sowers asked how much ISS research is currently funded by the private sector. Ms. Gatens said that in almost all cases, the research PI is already funded by his or her institution, or a grant from elsewhere. Any NASA funds go to implementation or partner costs, and researchers get launch and crew services from ISS. PIs often bring in external funds from the companies themselves. The overall ratio is about 4:1, CASIS to external (not including the launch). About 75% comes from outside of NASA. Other government agencies include NSF (\$5M/year), and NIH (a few million/year). NIH is doing another round of cell-based chips. ISS has agreements with over 20 commercial service providers who have facilities on ISS, and the companies are bringing other customers in. The question is how much these companies would pay for launch and crew time. The model is not self-sustaining just yet.

Asked why ISS could not be left in a higher orbit, Ms. Gatens said this would not be practical. NASA has looked at what it could take to boost Station to a “parking” orbit and concluded it would take about 100 times the propulsion needed for de-orbiting. ISS can’t be taken apart, and there is no Shuttle to bring home whole modules. ISS is looking at items that can be safely brought down and preserved, and there will be an opportunity to transfer items to the Axiom station. NASA did ask what it would take for a commercial company to take over ISS, but not a lot of interest was shown as the result of an RFI. Dr. Stofan said she had been communicating regularly with the Smithsonian Institution, planning for museum preservation of certain ISS items.

Commercial Space Division Programs

Mr. Phil McAlister presented an update on NASA’s Commercial Space Division and reported on Commercial Crew Program (CCP) flight accomplishments to date. CCP is getting ready for Crew 8 and is proud to represent a new chapter in human spaceflight while staying vigilant, staying safe, and never taking safety for granted. This is a tremendous pace for a relatively small team, and they handle it very well. Crew 6 returned on 10 September after 186 days on orbit and flew some non-NASA astronauts as well. The Crew 6 vehicle did a fly-around on ISS, and landed in Jacksonville, FL for the first time in the history of CCP. The sea states (5-foot waves, 5-knot winds) were higher than in the past, but still within flight rules. Crew-7 launched on 26 August and docked on 27 August. The launch was delayed one day for a valve checkout; this delay was at SpaceX’s recommendation, demonstrating that the company takes safety very seriously. There are now 13 weeks to go until the launch of Crew 8; the vehicle is processing now, with about 18 days of schedule margin. Crew Flight Test (CFT) is scheduled for mid-April 2024, and is on track for the launch; it will be the first American-made orbital crew capsule to land on land with crew, and the first launch of crew from Cape Canaveral since 1968. All Orbital Flight Test-2 (OFT-2) inflight anomalies have been closed. Two issues remain, but are essentially complete: tape remediation, and parachute soft link joint issue remediation. Further parachute testing is imminent; if it goes smoothly, then the April target launch should be achievable.

Other miscellaneous CCP activities include preparation of Pad 40 as a backup, strengthened coordination with the Commercial LEO program, and Collaborations for Commercial Space Capabilities. NASA agreements with Blue Origin (Space Vehicle), Sierra Space (Crewed Dreamchaser), and SpaceX (Dragon and Starship) gives the Agency much insight into these

vehicles. In addition, CCP is spending a lot of time on Lessons Learned. Insights include: mature, stable requirements and well-defined ISS interfaces led to stable design resulting in cost control, and integrated vehicle and software testing, including abort tests, have been a key to success. Areas for improvement include a conclusion that NASA involvement in detailed component level design, detailed system design reviews and additional hardware and system level integrated testing could have identified problems earlier.

Mr. McAlister said he had spent a lot of time with Jim Free's HLS team, talking about procurement approaches. The CCP contracts have worked very well and have shown themselves to be stable and cost-effective. Face-to-face communication of these lessons has been quite important. Mr. McAlister considered the number one CCP lesson learned was how important it was to have mature, stable requirements and well-defined ISS interfaces. CCP also owes a debt to the Commercial Orbital Transportation Services (COTS) team, for their legacy and experience. Mr. McAlister felt that the Commercial Crew Program has saved the Agency \$20-30 billion over the life cycle of the program.

After reviewing CCP's top successes and areas for improvement, Mr. Ebersole asked if a correlation could be made regarding the stable requirements and fewer engineering change proposals. Mr. McAlister said he'd take that action under advisement. Mr. Hale asked what lessons had been learned about contracting mechanisms, as there tends to be a lot of angst over Firm Fixed Price (FFP) contracts where there is development involved. Mr. McAlister said contract vehicles depend on the nature of the mission. FFP doesn't make sense for all applications. When Commercial Cargo was being envisioned, there was no commercial cargo service, so NASA had to assist in the technical development. As an example, the Commercial Lunar Payload Services (CLPS) activity is great but landing on the Moon is very difficult. It might have been better as a partnership instead of a services purchase and that might have hastened development. For a lot of lunar applications, it's not obvious how the private sector partner is going to commercialize that capability; it is very expensive and technologically challenging.

Mr. McAlister presented the overall plan for the ISS to Commercial LEO Destination (CLD) transition. The plan is to retire ISS in 2030 via a two-phase approach, using the same model that was used for Commercial Crew. While the schedule is a risk, Mr. McAlister said that did not indicate a safety risk since the program is not schedule driven. To mitigate the schedule risk, CLDP is working with multiple partners (Axiom Space, Sierra Space/Blue Origin, Nanoracks) to maximize the use of competition to reduce risk. Ideally, there will also be an overlap period between ISS retirement and CLD establishment which provides some schedule margin. Also, if the CLDs are not ready, NASA could request an extension for ISS. If all of those mitigations fail, then a temporary gap would occur. While a gap would not be good, Mr. McAlister believed it would be recoverable. NASA faced a similar situation when Shuttle was retired and we had a gap in human space transportation for almost a decade and we recovered quite well. Another consideration is that the Dragon and Starliner vehicles could be used as mini-stations for short duration missions. By 2030, many more commercial options might be ready, which NASA could use to help reduce the impacts of a gap in LEO destinations.

NASA has no experience in how to operate CLDs as a business; this is the reason for a two-phase approach. The first phase will allow providers to close their business case studies. There are signs that commercial providers are already making decisions (e.g., Boeing/Nanoracks) that reflect evolution of business case trades. Dr. Condon asked: are these CLD providers providing out of the box solutions that are economically feasible. Mr. McAlister said NASA holds a quarterly management review with these partners to maintain this insight. Each partner has different views of the market. Blue Origin has a large vehicle and has interest in the personal space travel market. Nanoracks has spent much time on the science market. Axiom Space is focused on all potential markets. Northrup Grumman was mostly focusing on the government market. Mr. McAlister said he was pleased with progress thus far.

SubC (Suborbital Crew Program) is still working the safety case. NASA is using an evidence-based approach to judge how these companies approach human rating. There is a potential for human-tended payloads; there are several ideas that are very good candidates for suborbital flights. Suborbital has great potential for doing things differently.

Recusal Note: Mr. Alibaruho recused himself from the Commercial LEO presentation

Commercial LEO Destinations

Ms. Hart presented a status of CLD. Today NASA has 3 CLD current partners. Since 2020, using ISS as a platform, NASA continues to make SBIR awards, establish unfunded agreements, work Phase 2 transition requirements, and work private/public partnerships. Many internal partner milestones are going on, not shown in the presentation charts. Key accomplishments in 2023 include: Nanoracks/Voyager as part of Starlab Station, announced a trans-Atlantic Joint Venture with Airbus and is teaming with Northrop Grumman; Orbital Reef and Sierra Space completed a stress test of an inflatable LIFE Habitat; and fabrication for the first two modules of the Axiom Space Station are underway. In addition, Orbital Reef completed their burst test of the Sierra LIFE Module in December of 2022. The partnership of Nanoracks/Voyager with Northrup Grumman is seen as a strengthening aspect. Blue Origin continues their partnership with Sierra Space. While Northrup Grumman terminated its funded SAA, this does not affect their Unfunded Space Act, and they continue to support Nanoracks. Nanoracks held their Starlab System Readiness Review milestone in June 2023. NASA continues to work with Axiom the company plans its subsystem CDRs in 2024.

Requirements Development Status

One major milestone for requirements development was RFI #3. NASA received a number of comments from many participants and will work the RFI in earnest in early December. The RFI did not include the unique requirements and verifications associated with cargo or utilization. Areas not included in the draft will be updated in future revisions. Key questions asked in RFI #3 include: Are there any requirements or standards that are unclear, conflicting or ambiguous? If so, what are the recommended improvements?

Ms. Hart noted that CLDP released a new common docking standard as part of the RFI, as a response to industry feedback, and will be evaluating those comments as well. Mr. Voss asked: are we procuring anything other than standards or requirements? Hardware? Ms. Hart said the original intent is to purchase services only and not to purchase any hardware. However, there are

some trades on the utilization requirements associated with what kind of facilities that the provider might build vs what may be provided by NASA. For example, many NASA and Non-NASA customers are interested in science gloveboxes, so NASA will provide some requirements for these knowing the provider plans to build them. Other unique NASA payload systems may have to be provided by NASA.

NASA is procuring services only (launch and crew, and science up and down services, time on orbit, etc.). Via the Funded SAA, NASA has specifically defined business and market milestones to understand partners' business cases and potential future costs, such as establishing daily rates for crew and science activities. Ms. Hart expected that there would be rates for accommodations, such as those that hotels charge for conferences on site.

Collaborations for Commercial Space Capabilities-2 is a second series of unfunded SAAs with US industry to support the development of new space capabilities relevant to NASA's exploration strategy. NASA competitively selected 7 companies in June, including Blue Origin and N-G Systems Corp. The N-G award was for a crew-tended persistent platform that works with N-G's free flyer. Sierra Space has a Pathfinder CLD with inflatable module and Dreamchaser vehicle for Crew and Cargo. The budget is small, but NASA is trying to support as many efforts as possible. Notably, the program kicked off the partnership effort in September/October and received over 100 requests for information from the participating companies. SAAs follow the schedule of the partners.

PAMs

The Axiom-2 crewed completed its mission successfully and is continuing to learn and grow with Axiom. The Axiom-3 crew has been named, and the Axiom-4 mission has been awarded. Mike Lopez-Alegria will return as commander for Axiom-3, which has completed its vehicle baseline review. Crew training began in June, with launch planned for 10 January. One major change being assessed is the use of SLC-40 for the PAM-3 launch. NASA launches for SLC-40 are also being considered for certification. Launch dates for AX-4 are still being assessed. NASA is evaluating future solicitations for PAMs 5 and 6.

Ms. Hart noted that CLDP is seeing a lot of investment, but as NASA moves to costly and long-lead items in Phase 2, certification will be critical. Dr. Condon asked how Congress viewed CLDP. Ms. Hart believed the mood is favorable on CLD, and thought the bigger questions are about timing and budget. The CLD schedule to support an ISS EOL in 2030 is aggressive; any delay will put that schedule at risk. Mr. Hale asked how likely someone will be ready to go in 2030? Ms. Hart said the schedule won't be clear until the Phase II contract, CDR, and certification plans are in place. Industry has shown themselves to be willing to test out low-TRL items on their own dime, which helps a lot. CLDP is also working closely with ISS to put some meat on the transition plans, and to identify KDPs in 2025/26. If NASA sticks to the plan, Ms. Hart felt there would be some initial operating capability in time for EOL.

SCaN

Ms. Susan Chang, Acting Assistant Deputy AA, presented an update on the Space Communications and Navigation (SCaN) program, which currently supports over 100 missions, large and small, from pre-Phase A planning to Phase E operations which is an around-the-clock

effort. SCA_N also has wide responsibilities in managing national and international spectrum management forums and leads NASA's interagency efforts in positioning navigation and timing (PNT). SCA_N is adapting to rapid changes in the space sector, which includes major growth in commercialization, and cis-lunar developments. SCA_N operates Deep Space Network (DSN) stations in Canberra, Goldstone, and Madrid. There is limited use of 70m antennae at each station; there are 3-5 34m antennae at each station that are easier to maintain.

As of 2022, 60% of all Direct to Earth (DTE) services to NASA missions are being provided through commercial and non-NASA partners. NASA is now evaluating the growing market of DTE commercial sources (AWS, Leaf Space, etc.) for further services. Kongsberg Satellite Services (KSAT), which began in the 1990s, laid a lot of the groundwork for this effort. NASA released a 2023 RFP with the intent of expanding the level of commercial DTE services to nearly 100%. For near-Earth relay, NASA's Tracking and Data Relay (TDRS) satellites are aging; TDRS is ramping down and will be down to 4 satellites in the mid-2030s. Current missions need to understand that this government-provided capacity is declining. NASA continues to make progress in pursuing commercial services to take over TDRS capabilities. NASA, through SCA_N's Communications Services Project (CSP), awarded funded space act agreement (FSAA) awards totaling of \$278.5M. The awardees included Inmarsat, Amazon's Project Kuiper, SES Govt Solutions, SpaceX, Telesat, and Viasat. Subsequent to the FSAA-funded demonstrations, an open competition will be held. Ms. Chang noted that missions might have to be encouraged to move to new providers.

For the deep space mission support, NASA is working with the international partners in Spain on updating the government-to-government agreement to provide DSN services to missions and will need to renegotiate its contract with Australia in the future. DSN supports 42 missions at present, with 41 missions planned to come online. Mr. Hale addressed some of the communications glitches that occurred during Artemis I, noting that HEOC is concerned that there is not enough DSN capacity to cover all of NASA's planned missions. Ms. Chang said that JPL, which manages DSN, recognizes this and is spending a lot of time analyzing DSN needs for the Artemis missions. Ms. Budden commented that NASA partners with DoD, which can increase the load, as can the increased use of cubesats. Ms. Chang said JPL is considering all of these factors, and that JPL also cites inadequate funding for building up staff. JPL is working to identify other areas of concern. Staffing changes are coming as well in early 2024.

DSN clearly cannot support all the demand. A total of 3.5 DSN antenna equivalents were needed over the 26-day Artemis I mission, plus 8 CubeSats (871 hours). Existing SMD missions lost 1585 hours of coverage during the Artemis I mission, and maintenance time was lost as well. SCA_N plans to support lunar demand with new DSN capacity and upgrades; the construction of a Lunar Exploration Ground Sites (LEGS) network; lunar communication and navigation relay services; and international partnerships and contributions. Mr. Hale asked if there were any firm commitments or schedules. Ms. Chang said it was a work in progress. JPL is working on determining where additional 34m antennas can be useful. Mr. Bowersox noted that all these things can be done only if NASA gets the required resources; the SCA_N team has all the plans laid out. Mr. Hale commented that missions can't be conducted without communications resources. Artemis will be covered, but there will have to be trades and deconflicting exercises. Dr. Stofan noted for the record that this tension has been going on forever, and that there is

nothing that can replace the DSN. Mr. Hale agreed it was a deeply concerning situation. Mr. Bowersox shared the sentiment.

Ms. Chang reviewed DSN's Road to Green initiative, as well as the DSN aperture enhancements project. A DSN Futures Study, currently underway, will determine further enhancements, depending on resource availability. Other upgrades include use of Optical Communications Technology Demonstrations on missions, and SCan technology investments that are being driven by mission needs, such as a Galactic Positioning System (X-ray navigation) and a Deep Space Atomic Clock. Ms. Chang closed with a brief summary.

Launch Services Program

Mr. Bradley Smith gave an update on the Launch Services Program (LSP), first presenting an organization chart showing how LSP fits into the Agency. LSP staff has an average experience of

16.2 years on the job, and 45% of LSP employees have advanced degrees. The program provides launch vehicle (LV) and full-service acquisition and mission assurance under National Launch System (NLS) auspices, and limited mission assurance services for other users. The Launch Services Office has taken on the responsibility of the newer LOX/Methane launch vehicles for the whole government. LSP also manages the Flight Planning Board, dealing with companies like SpaceX, which wants to launch numerous flights. LSP must work to deconflict many missions. The question of who is going to regulate on-orbit authority is still open. There needs to be a regulatory framework, and NASA continues to work with FAA and Commerce to find a good path forward.

Ms. Amanda Miskevitch leads LSP, and some new hires include Albert Sierra, Tim Dunn, and Jorge Piquero. There is a surge of retirement that is happening in both NASA and across the aerospace industry, and NASA needs to keep this in mind. LSP has resident offices across the US, although the majority reside at KSC, and there is also a sizable office at Vandenberg Air Force Base. NASA is thinking about whether LSP needs a presence at Boca Chica, TX. Other functions of LSP include commercial acquisition expertise, formalized government collaboration, program management, analysis, engineering, integration and launch operations. LSP's current fleet includes the NGIS Pegasus XL. NASA hasn't flown the Pegasus XL for some time, which is a concern. The ULA Vulcan will be launched for the first time on 24 December. Blue Origin's New Glenn has not flown yet. LSP primary missions have included 102 launches since 1998: LRO/LCROSS, Juno, all the Mars rovers, Solar Probe, and OSIRIS-REx. There have been two failures, thus LSP has a 98.5% success rate. Most recently LSP launched Psyche, on 13 October, which achieved an orbit that was well within ICD requirements.

LSP advanced planning and awarded missions in flow comprise over 75 missions at present, from core missions to helping mission directorates with advance planning for missions toward the end of decade. Emerging launch services include VADR, which had its origins in 2014/15, when Earth Science's Michael Freilich partnered with LSP to introduce the Venture Class Launch Service, which relied on commercial launch vehicles. VADR has been tremendously successful, and most recently launched the TROPICS cubesat mission, and TSIS-2 (SpaceX). VADR now includes Firefly, partnered with Northrup Grumman, which can provide a Delta II

class payload LV for the Earth Science Division (ESD). LSP also does a lot of mission assurance for Commercial Crew and Resupply.

Mr. Smith said that LSP's evolving future is also of some concern to him. LSP flies 4-6 missions per year, typically, but when Gateway/Artemis comes on board, its needs will stretch LSP. The CubeSat Launch Initiative (CLSI) continues to provide great benefits to education organizations, providing up to \$300k to cover launch and integration. CLSI received 20-30 proposals from colleges, high schools, and a middle school. CLSI also helps boost Diversity, Equity, Inclusion, and Accessibility (DEIA), and partners with OSTEM to track how many CSLI participants have gone into aerospace careers.

In 2024, LSP will be launching PACE, GOES-U and Europa Clipper. PACE has been shipped. The next VADR missions will be PREFIRE and ESCAPADE. ESCAPADE was originally going to fly with Psyche, but LSP is happy to have another LV on its manifest.

Mr. Smith concluded by saying that launch is really hard, and still incredibly punishing, but he regarded his primary as assuring these LVs will fly.

Discussion

Mr. Hale said he was pleased to see how successful LSP has been. Mr. Alibaruho asked whether the Blue Origin launch scheduled for August 2024 had been preceded by flight testing. Mr. Smith said they are working hardware, and willing to take a risk with a Class D payload. He said he had seen the schedule but didn't have deep insight into their process. He noted that there have been no rides yet on Terran I, and that it appears they are going straight to Terran R. In response to another question, Mr. Smith said that over the last 10 years, he had learned more about capital expenditures and burn rate projections, and how they can cause launch failures. He added that he had learned to take into consideration the vagaries of the market and had been talking with venture capitalists to gain further insights.

Public Comment

Lauren Holt: Can we discuss nuclear propulsion and power work, and how it will affect future space flight? Mr. Hale said he resonated with the comment and that HEOC would explore it further.

Brian Harvey: enjoyed Chang's comment on tapping international partners to help the Artemis program. Ms. Cline said the general rule of international participation is no exchange of funds. If an international partner is willing to provide services, it would be a contribution, not a procurement. For example, the Canberra site could contribute an antenna. NASA can also accept an international service, like time on a satellite.

Comment: the situation with DSN was disturbing, HEOC should keep an eye on DSN. Can commercial augment DSN capabilities?

Discussion

HEOC discussed a recommendation to increase emphasis on SEI and risk management for Artemis, at the Enterprise level. Dr. Sowers felt the recommendation should be directed to the ESDMD AA. Ms. Budden supported the finding and recommendation, and HEOC agreed that it

should go to the AA. Mr. Ebersole said that Artemis briefings had been more of a high-level discussion, and that he lacked a clear understanding of criteria, processes, and due diligence. Some questions to ask: What are the top things the AA is worrying about? How do you allocate budget to mitigate risk? Dr. Sanders said that the Aviation Safety Advisory Panel (ASAP) had looked at the new program offices and found that they do have an executing process that seems to be working well to getting to projects and programs at a sufficiently early stage, while integrating a lot of legacy programs. She recommended that HEOC take a closer look at them, however. Mr. Hale agreed that henceforth, the MD briefings should be contain more details. Dr. Sanders agreed that a hugely complex and challenging agenda should garner more attention.

Mr. Hale also suggested a more detailed discussion of risk management at the next HEOC, and perhaps a fact-finding visit to relevant programs and projects.

Mr. Hale commented on the encouragement that the Agency has been giving about the importance of Artemis and beating the Chinese to the next lunar landing. The lunar architecture is not designed for a race, but for long-term, sustained operations. He worried that this is setting the wrong expectation. He was not sure it rose to the level of a finding, but he said this would be a talking point for an outbrief to the senior management. Dr. Condon said that Mr. Hale's observations need to be communicated to senior leadership at the highest level. Mr. Hale agreed that it was an appropriate subject for his exit interview. Mr. Voss felt it should be documented at the HEOC level as a finding or recommendation. Dr. Sowers felt it might be that the Administration is couching Artemis in terms of a race to drum up political support. Mr. Alibaruho said that the goal may not be first to the Moon; the victory is building a stable presence on the Moon, which would leverage the competitive aspect of the race. Mr. Hale said he was not ready to write it up and will consider the thought further.

Mr. Alibaruho raised a thought, saying he Mr. loved Smith's presentation on LSP providers, but that he got a sense from the presentation that the Agency may not have the same penetration into these companies, a reason for concern. He thought HEOC should upgrade the business analysis insights at LSP to better understand the real capabilities of the providers. Mr. Hale thought the government is more aware than it appears, and they're simply not showing their hand. He said he wouldn't discourage Mr. Alibaruho from buying coffee for Mr. Smith and having a chat. Businesses have a lot of concern for proprietary information, which may account for some of the opaqueness of LSP briefings.

Mr. Hale felt that HEOC should go on record about the critical importance of the DSN network and infrastructure and suggested the following recommendation: NASA needs to emphasize the requirements for expansion of the DSN, and NASA needs to immediately complete plans to expand the capability of the DSN. Ms. Budden said she would add "maintenance" to the recommendation. Dr. Condon thought HEOC should comment on making funding available to make the upgrades happen. Dr. Sowers said he was confused about what LEGS can do for the cis-lunar missions. LEGS also has a commercial partner element, and it is not clear how the demand will be apportioned. Should HEOC recommend that LEGS be made large enough to cover cis-lunar completely? Mr. Hale added wording to the recommendation, to the effect of: HEOC is unsure that LEGS will provide enough relief to the DSN to allow the missions to be

supported. Ms. Budden noted that HEOC also doesn't know how the priorities are set, and who makes those decisions. Where does NASA come into the queue?

Ms. Cline appreciated the voicing of issues and felt she got better sense of what the issues were. Mr. Hale said he'd been pleased with the SOMD briefing and felt ESDMD had been more abstract. He said he would add these concerns as more exit interview material, and that the Committee needs more in-depth briefings. Ms. Budden suggested providing a list of questions to briefers in advance of meetings. HEOC concurred.

Mr. Hale said that if there is a NAC meeting before his appointment expires, he would bring up the full list of concerns, and if not, would have it written up for the incoming Chair. Mr. Hale expressed his appreciation for HEOC's unique insights and invited everyone to keep in touch. Dr. Siegel adjourned the meeting at 3:50 pm.

For NAC Recommendations (actionable):

Short Title of Recommendation: Shortfall in NASA Deep Space Communications Network

Recommendation: NASA needs to emphasize the requirements for expansion and sustainment of the DSN. NASA needs to immediately complete plans for and fund the expansion of the capability of the DSN.

Major Reasons for the Recommendation: The DSN capabilities may not be able to support the expected cis-lunar, Lagrange, and deep space missions of the future unless steps are taken to expand capabilities. These infrastructure items have long lead time requirements and need to be addressed immediately. Resources, especially appropriations, need to be a high priority. The committee is unsure if LEGS will provide enough relief to the DSN to allow all the missions to be supported.

Consequences of No Action on the Recommendation: Without increased capabilities, lack of communications capability will stifle the plans that US and its allies have developed for deep space operations.

For NAC Findings (not actionable):

Short Title of Finding: Increased Emphasis on Systems Engineering and Integration (SEI) and risk management for Artemis.

Finding: The complexity of the Artemis missions dramatically increases for Artemis 2 and beyond. Each mission involves many elements and interfaces. Successfully executing these missions will require an increased emphasis in SEI as well as risk management at the enterprise level and within each program element.

Appendix A

Agendas

NAC HEO Committee Public Meeting – Exploration Systems Development Mission

Directorate

Friday, November 17, 2023

9:00 – 9:05am	Opening Remarks	Dr. Bette Siegel/Mr. Wayne Hale
9:05 – 10:00	Exploration Systems Development Mission Status	Mr. Jim Free
10:00 – 11:30	Moon to Mars	Ms. Lakiesha Hawkins
11:30-12:30	Lunch	
12:30 – 1:30	Strategy and Architecture	Ms. Nujoud Merancy
1:30– 1:35	Public Comments	
1:35 – 3:00	Discussion and Recommendations	
3:00pm	Adjourn	

Dial-In and WebEx Information for November 17, 2023

*** All times are Eastern Time ***

Event address for attendees:

<https://nasaenterprise.webex.com/nasaenterprise/j.php?MTID=mde213f73124d28623e6f87080ef007e5>

Event number: **2760 298 4582** and Event password: **Kzfr88Mef3\$** (case sensitive)

If needed, the U.S. toll conference number is **1-929-251-9612** or **1-415-527-5035** and access code is **2760 298 4582** and password is **59378863**

NAC HEO Committee Public Meeting – Space Operations Mission Directorate

Monday, November 20, 2023

9:00 – 9:05am	Opening Remarks	Dr. Bette Siegel/Mr. Wayne Hale
9:05 – 9:35	Space Operation Mission Directorate Status	Mr. Kenneth Bowersox
9:35 – 10:30	International Space Station Update	Ms. Robyn Gatens
10:35 – 10:45	Break	
10:45 – 11:30	Commercial Crew	Mr. Phil McAlister
11:30 – 12:15pm	Lunch	
12:15 – 1:00	Commercial LEO development/Commercial Space Stations	Ms. Angela Hart
1:00 – 2:00	Space Communications and Navigation	Mr. Jeff Volosin
2:00 – 3:00	Launch Services	Mr. Bradley Smith
3:00 – 3:05	Public Comments	
3:05 – 4:30	Discussion and Recommendations	
4:30pm	Adjourn	

Dial-In and WebEx Information for November 20, 2023

**** All times are Eastern Time ****

Event address for attendees:

<https://nasaenterprise.webex.com/nasaenterprise/j.php?MTID=m5b8c7a6f8cce36e7e36e3cb560959a71>

Event number: **2762 899 7482** and Event password: **bnZydZM*683** (case sensitive)

If needed, the U.S. toll conference number is **1-929-251-9612** or **1-415-527-5035** and access code is **2762 899 7482** and password is **26993960**

Appendix B
HEOC Membership

Mr. N. Wayne Hale, Chair
Retired, NASA

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

Webex Attendees

Eracenia Kennedy	Elaine Slaugh	Lucia McCullough
Jim Free	Norm Knight	Paul McConaughy
Marlana Dorman	Dayna Ise	Kelly O'Rourke
Neil Mallik	Lena Burleson	Nantel Suzuki
Sasha Ricks	Ann Zulkosky	Anton Kiriwas
Lucia McCullough	DeAnn Reilly	Kelsie Krafton
Joan Zimmermann	Paul Marshall	Rhonda Bourn
Joe Folsom	Chris Gilbert	Rachel Kraft
Barry Jenakuns	Andrew Maynard	Tonya Woodbury
Sridhar Gorti	Lisa W-M	Stephanie Schierholz
Gene Mikulka	Zoe Wai	Sean Fuller
Maritza Alexander	Gabe Merrill	Ashley Peter
Christine Solga	Janet Karika	Tim Finkel
Catherine Koerner	Devin Bryant	Bev Perry
Veronica Miller	Ed Mohr	Kimberly Schuster
Lakiesha Hawkins	Jonathan Krezel	Lora Bleacher
Ned Penley	Mike Tax	Barbara Adde
Marcia Smith	Quincy Harp	Greg Mercer
Philip Sloss	Mary Lynne Dittmar	Heather D. Smith
Tammy Flowers	Linda Karanian	Nujoud Merancy
Brian Dewhurst	Herman Moyer	Robert Zimmerman
Kathryn Hambleton	Roger Rudig	Matt DeRosier
Karin Sturm	Kailey Melton	Abby Braswell
Erin Stuart	Kimberly Cashin	Lucia McCullough

Kyle Griffin
Dana En
Vida Beard
Brian Harvey
Connor Mason
Jeremy Fehrenbacher
Matt Derosier
Lewis Groswald
Vanessa Lloyd
Catherine Williams
Miles Doran
Richard Rogers
Emily Braswell
William Harwood
Francesco Bordi
S. Lanier
Praxedis Flores
Grant Tremblay
Stephen Clark
Ramzi Masri
Patricia Moore
Danny Lentz
Scott Karn
Jiří Hošek
Carrie Rogers
Julie Mules
Eoghan McFadden
Sue Chang
Kevin Foley
Ashlee Wilkins
Jamie Favors
Elisha Sauers
Eddie Semones
Jeremy Fehrenbacher
Barret Hoffstetter
G. Heckler
Lora Bleacher
Kathryn Hambleton
Kiersten White
Erin Kennedy
Lucia McCullough
Kenneth Chang
Christine Solga
Marika Gray
Patrick Morris

Christopher Stelter
Sean Fuller
Jeffrey Fesler
Tonya McNair
Mark Carreau
Bradley Smith
Ken Bowersox
Eric Maier
Robyn Gatens
DeAnn Reilly
Alicia McPhail
Danny Lentz
David Millman
Chris Kunstadter
Donna Shafer
Gabe Merrill
Miles Doran
Kathy Nado
A.C. Charania
Andrew Maynard
Kailey Melton
Jeff Foust
Richard Rogers
Richard Irving
Original Gram
Kelsie Krafon
Jacob Keaton
Jonny Pellish
Kevin Metrocavage
Misty Snopkowski
Laura Forczyk
Noreen Dahl
Irene Klotz
Paul Frazier
Alicia McPhail
Janet Anderson
Benjamin Ashman
Brittani Sims
Mary Lynne Dittmar
Lauren Holt
Darryl Gaines
Jim Way
Charlene Jupiter
Panita Van Besien
David Payne
Heather Scott

Bradley Stewart
Ramzi Masri
Kevin Foley
G. Heckler
Phil McAlister
Gale Allen
Don A Nelson
Chris Gilbert
Nichole Felix
Barbara Glisan
Philip Baldwin
Yuichiro Inokuchi
Eric R Berger
Zoe Wai
Yuichiro Inokuchi
Joshua Finch
Angeliki Kapoglou
Barret Hoffstetter
Zudayyah Taylor-Dunn
Ashlee Wilkins
Heather Scott
Angela Hart
Angela Peura
James Miller
Chris Kunstadter
John Rummel
María Alejandra
Barbara Adde
Philip Baldwin
Evelyn Miralles
Lauren Morgan
James Lochner
Kenneth Perko
Milenka Bascope
Alicia McPhail
Andrew Maynard
Janet Anderson
Wm. Horne
Benjamin Ashman
Marika Gray
Megan Tomasso
Neil Mallik
Vida Beard
David Eisenman
Don A Nelson
Daniel Clifft

Steve Koerner
David Payne

L Dillon
David Cunniff

Jackie Wattles
Dmitriy Zaytsev

Appendix D

Presentations

1. Status of Exploration Systems Development Mission Directorate; James Free
2. Moon to Mars Status; Lakiesha Hawkins
3. Mars Campaign Office; Lakiesha Hawkins
4. Moon to Mars Architecture Update; Nujoud Merancy
5. Space Operations Mission Directorate; Kenneth Bowersox
6. International Space Station Status; Robyn Gatens
7. Commercial Space Division Programs; Phil McAlister
8. Commercial LEO Status; Angela Hart
9. Commercial LEO Destinations; Angela Hart
10. Space Communications and Navigation (SCaN) Update; Susan Chang
11. Launch Services Program; Bradley Smith