

PLANETARY SCIENCE ADVISORY COMMITTEE

July 9-11, 2024

MEETING REPORT

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Date: 2024.10.01 12:07:24 -07'00'

Dr. Hope Ishii, Chair
University of Hawaii at Manoa

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Dr. Katharine Robinson, Executive Secretary
NASA Headquarters

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*Prepared by Ms. Ashley Mae
Tom & Jerry, Inc.*

July 9, 2024

Welcome & Introductions

The Planetary Science Advisory Committee (PAC) Designated Federal Officer (DFO) Executive Secretary, Dr. Katie Robinson, opened the meeting. Dr. Robinson explained that the meeting was open to the public and hybrid while complying with the Federal Advisory Committee Act (FACA). Dr. Robinson completed roll call and noted that quorum was met for the meeting.

Dr. Hope Ishii, Chair of the PAC, welcomed all members of the PAC and those attending the meeting. Dr. Ishii completed roll call and noted that quorum was met for the meeting. She gave brief instructions regarding the scope of the PAC, communication, questions, and notes. She informed the community of the public comment periods to be found in the agenda.

Dr. Ishii introduced Dr. Gina DiBraccio, Acting Director of the National Aeronautics and Space Administration (NASA) Planetary Science Division (PSD). Dr. DiBraccio thanked all attendees and the PAC members.

Mars Sample Return Internal Review Board Response Team

Dr. Paul Hertz, Science Mission Directorate (SMD) Senior Advisor, was introduced to present the Mars Sample Return (MSR) Internal Review Board (IRB) Response Team (MIRT) update. Dr. Hertz thanked the PAC for the opportunity to present and stated that Dr. Sandra Connelly chaired the MIRT.

For half a century, NASA has engaged in a systematic effort to determine the early history of Mars and to assess its biological potential as a pathway to understanding the formation and evolution of habitable worlds - including Earth. This joint campaign with the European Space Agency (ESA) is a pivotal step in a decades-long, carefully developed strategy to understand Mars, provide insight into planetary evolution, and understand the potential for life on other planets. MSR has been a top priority of the last two Planetary Science Decadal Surveys.

Perseverance has collected, and will continue to collect, highly valuable science samples that will answer key questions about the geological history of Mars, its climate, and whether life could have developed on Mars. Only state-of-the-art laboratories on Earth can fully analyze and detect the faint signatures that unlock the answers to these key questions in planetary evolution and astrobiology. Samples from Mars are unique because it is the only planet in the solar system capable of sustaining life which can be readily explored on the surface through science investigations and future human explorers.

MIRT efforts took place between October 2023 and March 2024. They conducted roughly 70 interviews with programmatic and science stakeholders. Approximately twenty architecture variations were analyzed while conducting three formal Technical Integration Meetings (TIMs) and numerous lower-level studies and analyses. ESA and all other MSR organizations participated. The MIRT developed cost estimates for all architecture variations. It

did not develop new architecture for MSR. That NASA MIRT document is public and available [online](#).

The MIRT recommendations were developed for SMD decisions, which were presented for concurrence by the Agency. MIRT sub teams prepared final recommendations to the Core Team (CT). The MIRT CT deliberated on sub team reports and developed recommendations for the SMD Associate Administrator (AA). The SMD AA then made final recommendations to Agency leadership. The SMD AA briefed NASA Senior Leadership on determinations in response to IRB recommendations.

The budget that is being executed in FY24 is not the budget that had been planned for – noting a deduction in about a billion dollars. A lot of changes have had to be made. The PSD took on two thirds of the budget reduction. The planning budget request has been submitted for FY25.

SMD MIRT responses included revising the MSR mission design with improved resiliency, risk posture, and reduced complexity. They recommended maintaining NASA’s MSR Memorandum of Understanding (MOU) with ESA and launch Earth Return Orbiter (ERO) including the Capture Containment and Return System (CCRS) in 2030 and launching the Sample Retrieval Lander (SRL) with the Mars Ascent Vehicle (MAV) from Earth in 2035 to return the samples to Earth in 2040. They recommended that the returns be carefully selected from the diverse sample group collected by Perseverance. This recommended architecture would balance programmatic and technical risk and decouples launch readiness dates. It also adds Radioisotope Thermoelectric Generators (RTG) to SRL to improve reliability and MAV thermal environment. It would allow for a refreshing of telecommunications prior to SRL arrival. It allows for more time to mature SRL and MAV designs. It allows for the finalization of the Orbiting Sample design early to stabilize the overall mission design. It also comes with a Parametric Lifecycle Cost estimate of approximately 8-11 billion dollars which is consistent with IRB-2. The Agency has not adopted the current recommendation.

MIRT recommended included improving lines of accountability and authority. The IRB-2 suggested merging the Mars Exploration Program (MEP) and MSR, but the MIRT did not agree. MIRT suggested empowering the NASA Headquarters (HQ) MSR Program Office with all programmatic capabilities including system engineering and Project Planning and Control (PP&C) responsibilities. MIRT recommended elevating the MAV and Mars Orbiting Sample system (OS) to Level 2 Projects. MIRT recommended establishing Standing Review Boards (SRBs) for the MSR Program and MSR Level 2 Projects.

MIRT recommended improving communications and coordination within the Agency and with external stakeholders by expanding the frequency of engagement between with MSR Program Director (PD) and NASA Senior Leadership, like what occurred with the James Webb Space Telescope (JWST). MIRT also recommended competitively selecting one world-class Mars Chief Scientist to span MEP and MSR.

MIRT recommended exploring out-of-the-box architecture and mission element options by releasing a competitive industry study solicitation as soon as possible. They recommended

finding innovative or alternate architectures that could offer lower overall cost, lower annual cost, earlier sample return, and or less complex with lower risks. They felt that since OS and MAV drive overall mission size, complexity, and cost; studies should include alternative MAV designs. In parallel, they recommended engaging with NASA Centers and Jet Propulsion Laboratory (JPL) for additional out-of-the box architecture solutions. MIRT recommended that the architecture must be capable of returning samples collected by Perseverance from the surface of Mars to Earth, at least ten of them.

A Research Opportunities in Space and Earth Science (ROSES) solicitation was released on April 16, 2024, with an industry day of April 22, 2024. The due date for proposal submission was May 17, 2024, and selections were announced June 7, 2024. They are processing selections to get contracts out. They anticipate awards occurring in the middle of July. They anticipate interim written reports within 45 days after awards with an anticipated final written report and oral presentation by the end of October. Independent report evaluations will be completed by the end of December with an Agency path forward in early 2025. Information regarding the studies and companies can be found [online](#).

Given the budgetary constraints across the government, NASA will focus MSR funding on advancing formulation of mission components and capabilities that have a high likelihood of being used in any future sample return architecture such as maintaining critical heatshield critical analysis and development; continuing Back Planetary Protection development; and maintaining entry, descent, and landing critical analysis and development. They also plan on evaluating and appropriately incorporating relevant findings from funded industry and Center architecture studies.

In summary, MSR is a critically important mission; it has been a top priority of the past two Planetary Science Decadal Surveys and NASA is determined to find a path forward to return the valuable samples from Perseverance. The HQ MSR Program Office is beginning to implement specific programmatic recommendations from the MIRT such as enhancing PP&C capabilities, shifting campaign level systems engineering to HQ, and competitively selecting on world-class Mars Chief Scientist to span MEP and MSR. To move forward under government-wide budget constraints, MSR is pursuing out-of-the-box architecture solutions.

Dr. Hertz concluded his presentation and was available for clarifying questions and discussion.

Dr. Murrow congratulated the MSR team and community for their work on the architecture. He asked about the minimum number of samples but stated that he had heard ten as a minimum. Dr. Hertz stated that a minimum of ten would make the entire project “worth it.” Current architecture stands to return thirty. There is some operational complexity. Although it is a minimum of ten, the reference number remains at thirty. The MIRT report addresses many other aspects of the mission that he did not discuss at this time.

Dr. Murrow asked how the community is analyzing the Perseverance lifetime? Dr. Hertz stated that the program is looking at that. The program is doing additional length of life testing on the mechanical systems of Perseverance so that they can gain a better idea of how long it will

be expected to last. Due to the small sample size of rovers, it is difficult to garner a lot of data. But they plan on assessing a life-time limit on moving that they are comfortable with. In the late 20's/30's, they would reposition Perseverance to await the exchange of samples before putting it back out for science missions. It is imperative to maximize the lifespan of Perseverance to ensure its capabilities for MSR.

Dr. Murrow asked how the cached samples are being protected if something occurs with Perseverance? The architecture would have to be rethought. It has been descoped – but this architecture is dependent on the delivery by Perseverance. A risk evaluation and longevity study was completed by JPL, Dr. Steven Thibault stated, as well as operational approaches to help maximize Perseverance's life. They have confidence in its lifespan.

Dr. Jessup asked about the 2040 return and how that related to the original plan? Are there other options regarding moving it up or back as it relates to the budget? To do it earlier means spending more money every year. The point of the study was to look at ways they were spending money and how to reduce the total cost to still complete the project. It has been delayed for several years. The reason for the delay is the decoupling of the build. They are not on top of each other now to keep the annual cost down.

Dr. Curry asked about a possible "Plan B" if the cost or timeline of this 2040 date doesn't work. The Agency has not decided on plan A. These studies are being done and then it will be incorporated with the MIRT, original architecture, and then the Agency will make a path forward.

Dr. Woods asked if there were requirements on the diversity on the sites from the samples collected. The science team emphasized that the more diversity increases the science. All the samples are on Perseverance, they aren't making any choices right now that limits which subset comes back. Dr. Grant stated that there are guidelines for expectations of sample sizes.

Mr. Barbee asked about the mass size of the samples and if there are requirements. They do not have that number in their head. They are all the same size because the sample tube is the same size. Dr. Thibault stated that he could get the specific numbers.

Dr. Prockter asked how they came up with the architectural variations. Dr. Thibault said they started with functionality which broke into building blocks. The team then looked at all the options for the building block tasks and began building architecture. They established nine references architectures that were representative of a broader trade space so that could then attack those on an analysis level.

Dr. Murrow questioned the disconnect in the logic – there is no mass benefit in reducing the number of samples returned. Dr. Thibault stated that there is a mass benefit. That is one of the things in play in the studies that are under way. Dr. Hertz stated that they hadn't recommended less samples being returned, just that it could be a solution. Current architecture is beyond the sky crane's ability.

Dr. Murrow asked if industry studies were allowed to achieve a smaller MAV with only ten samples and if they do that – how will the savings be made? Dr. Hertz stated that industry

was told a minimum of ten samples. Saving 5kg doesn't ripple down to make the sky crane usable. Dr. Thibault said that they were also looking at transformative approaches. Sky crane has significant advantages, but we are not constraining the material to that. They want the community to think innovatively.

Dr. Jessup sought clarification – the sky crane is less mass and less cost but the ten samples – where did that come from? Dr. Hertz stated it came from the Three Forks cache.

Dr. Cable recused herself from any questions regarding this topic.

Dr. Grant asked if they were moving to a 2040 date with all the studies, building, etc. Dr. Thibault stated that they were not. They have some architecture that shows that it could be earlier. Dr. Jessup asked if he had any dates.

Dr. Grant asked about the workforce and if it would be kept and implemented into the 2040 timeline or would there be a step back to bring them back in? Mr. Gramling stated that the Centers are managing their workforce. Dr. Grant questioned if Centers feel that they can support the architecture. Mr. Gramling stated that the Centers are working on maintaining the critical capabilities. Dr. Grant asked again if the Centers felt that they could support this. It was stated that the Centers are trying their best.

Dr. Grant asked if there had been any discussion about “Plan B?” Dr. Hertz stated that they were working very hard. Right now, they don't have a Plan A or B. They are working to have something to present to the Agency and Congress before the FY25 budget.

Dr. Curry asked about Perseverance “going quiet” soon – how does the Agency retain that science? The Mars Exploration Program (MEP) will be briefing this afternoon and should be able to answer this question better. Dr. Thibault stated that going quiet doesn't mean turning it off. It will still be operational.

Dr. Ishii asked if next year's budget matches this year – how will this be impacted? Dr. Hertz stated that the request for MSR is 200 million dollars. That is not enough to build up to the flight units on the schedule and they would have to see what the actual appropriation is for FY25.

Dr. Ishii asked about the ESA impact? Dr. Hertz stated that their current desire is to support the ESA 2030 launch.

Dr. Murrow discussed the fact that MSR has a possible link to the Moon to Mars (M2M) Mission. Learning about Mars furthers the mission. How is this being leveraged? Dr. Hertz stated that returned samples would be informative for sending people to Mars. SMD is responsible for executing MSR, MSR is funded by the SMD budget.

Dr. Prockter asked how the Exploration Systems Development Mission Directorate (ESDMD) included in these discussions regarding the architecture? Dr. Hertz stated the ESDMD would benefit from MSR. They are fully included in the value of the samples returned. Dr. Prockter asked if they had any say in any of the architectural decisions. Dr. Hertz stated that to this day they had not requested anything.

The PAC examined the possibility of a recommendation associated with the link between M2M and MSR.

Mr. Barbee asked about the national priority of MSR. Dr. Hertz stated that their priorities are to respond to the Decadal Survey. The Survey stated that they should return samples.

Dr. Jessup discussed how the budget is within SMD – what does the PAC want this finding to look like? Can they engage this other directorate to assist in the MSR budget? The PAC must understand that there are different line budgets. Dr. Hertz stated that M2M would be presenting later, and that the PAC advises Dr. Braccio.

Dr. Murrow discussed national posture and its use in this situation.

Dr. Woods asked if there have there been opportunities to identify technologies, components, technologies, etc. that are shared among other missions? Mr. Gramling stated that Dr. Thibault is in communication and that it will get ramped up. Dr. Hertz stated that to some extent that happens naturally. Dr. Thibault stated that they are in conversation currently.

Planetary Science Division Update

Dr. Gina DiBraccio, NASA PSD Acting Director, and Dr. Shannon Fitzpatrick, NASA PAD Associate Director for Flight Programs, were introduced to present the PSD update. PSD leadership and new team members were discussed. NASA's budget for FY24 was included in the minibus bill passed by Congress and signed into law by the President on March 9, 2024. For FY23, they had 3.2 billion dollars, with a 3.3-billion-dollar request in the budget for 2024. The delta from the Presidential Budget Request (PBR) is \$666.5 million with a delta of \$483.3 million.

The reduction is mostly accounted for by reduced support for MSR. MSR is to be funded at \$300 million or more. Although appropriation allows up to the President's FY24 request for MSR, portfolio balance and the Decadal Survey guidelines within the fixed top line are a high priority. The operating plan is still being worked.

Within the FY25 PBR, they intend to explore, innovate, partner, and inspire as priorities within the budget. The highest priority is the successful completion of Europa Clipper, Dragonfly, and the Near-Earth Object (NEO) Surveyor. They want to support international partnerships with the Jupiter Icy moons Explorer (JUICE) with ESA, the Martian Moons eXploration (MMX) with the Japan Aerospace Exploration Agency (JAXA), the Rosalind Franklin Mission with ESA, and EnVision with ESA. They are working to ensure that the Decadal-recommended science investigations are included in the Artemis campaign and that they are supporting the stable cadence of future Commercial Lunar Payload Services (CLPS) deliveries to the lunar surface. They are wanting to support the Planetary Science research community to ensure continued scientific discovery from NASA mission data.

MSR was paused in FY24 while architecture studies are completed and the FY25 budget request is for \$200 million. The PBR supports the launches of Europa Clipper in October 2024 and NEO Surveyor in 2027. It also supports the Dragonfly mission, confirmed on April 16, 2024, for 2028. It supports three missions to study Venus including the Deep Atmosphere Venus

Investigation of Noble gases, Chemistry, and Imaging (DAVINCI) and Venus Emissivity, Radio science, Interferometric synthetic aperture radar (InSAR), Topography, and Spectroscopy (VERITAS) both of which are set to launch in the 2031-2032 timeframe. It also supports contributions to ESA's EnVision. MEP supports ongoing operation of five missions to Mars, including Perseverance and Mars Science Laboratory (MSL) along with new investments in technology to enable future Mars missions.

It supports a robust Lunar Discovery and Exploration Program (LDEP) which includes two CLPS awards per year in most years; annual Payloads and Research Investigations on the Surface of the Moon (PRISM) calls for instruments; Artemis science instruments including handheld instruments for astronauts and the Lunar Terrain Vehicle (LTV); Lunar Reconnaissance Orbiter Operations; support Lunar Trailblazer for planned launch in FY25; and Volatiles Investigating Polar Exploration Rover (VIPER) continuation/termination review took place and NASA is still formulating the decision on this cost.

Dr. DiBraccio discussed the planetary science highlights. The next New Frontiers, Discovery, and Small, Innovative Missions for Planetary Exploration (SIMPLEx) Announcement of Opportunity (AO)s are expected to be released no earlier than 2026. A new Planetary Technology strategy and project is working to provide integrated technology development for future planetary science missions. Pre-formulation studies of the Decadal-Survey recommended that the Uranus Orbiter and Probe mission begin in the current budget horizon. Investments in Open-Source Science to enhance transparency, inclusivity, accessibility, and reproducibility in publicly funded scientific research support SMD's transition to cloud computing services. Radioisotope Power Systems program investments in technology enable successful trips to distant solar system destinations with harsh environments which includes the development of the Dragonfly Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). The Planetary Data System data archives, which now span more than 50 years of NASA-funded research, will expand to include ground-based observations of Near-Earth objects (NEO). She discussed the Decadal Survey progress which included the integrated Lunar Science Strategy, future Mars Science plan, and a technology development plan. Dr. DiBraccio presented the planetary fleet chart with over 40 missions.

They described the mission updates including Dragonfly, the Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx), and Perseverance. She discussed how they are going back to Venus with three missions: DAVINCI, EnVision, and VERITAS. The PSD early career award winners were announced. They discussed community opportunities such as the Lucy Participating Scientist Program, Here to Observe (H2O) Program, Envision Science Working Team (SWT) Interdisciplinary Scientist A&O, and China's National Space Administration (CNSA) Chang'e-5 Lunar Samples applications. Successes were celebrated such as the total eclipse.

She touched on the Europa Clipper which is the next mission up in the que for launch which is aimed for October from Kennedy Space Center (KSC). Orbital insertion is expected around Jupiter in April 2030. Europa is currently in the Assembly, Test, and Launch Operations (ATLO) phase and all environmental tests are complete. An operational readiness test-2 was

completed successfully in May. The spacecraft successfully shipped from JPL to KSC and commenced final Integration & Test (I&T) activities. The final launch load of flight software (SW) was delivered and will be installed ahead of the System Test 4 in July. All preparatory work on the solar arrays was completed and is ready for final installation in July.

The Clipper team has a Tiger Team working on an identified issue with the metal-oxide semiconductor field-effect transistor (MOSFET) which is specific to this space craft and is linked to Infineon. It is possible that they may not meet radiation toleration specifications that the craft will see around Uranus and Jupiter. The team is carrying out extensive testing at Goddard and the Applied Physics Lab (APL). At this point, it is maintaining its schedule for launch as all work is happening parallel.

Why was this issue only found now? A Department of Defense (DoD) customer had identified this issue. The customer worked in a black realm, so it took communication and networking. JPL jumped on the issue immediately and Infineon was the only supplier. The issue is with MOSFETs from a specific lot. Infineon has since changed their process and is working on the issue. They are collaborating with NASA and the Tiger Team. The team is looking at how many are on the spacecraft, where they're located, and what type of impact could be seen. Other spacecraft out there are using the same ones but radiation at Europa and Jupiter is stronger. The JPL team is trying to assess this by looking at locations on the spacecraft to see what is at highest risk and to implement mitigation measures. The MOSFETs work as electrical switches and a switch that would not work is a big threat.

What was the reason it was not found earlier? They were alerted at the professional conference because the MOSFETs passed the military specifications (MILSPEC) which is a widely used industry standard. However, they do not meet specifications at the higher tolerance for the duration that is necessary for Europa Clipper. The MILSPEC doesn't look at both the duration and the radiation level. There are a couple of options including annealing which can be used during flight to repair radiation damage, or the team could turn some of the MOSFETS off if they don't need to always be on. The level of risk won't be known until testing is finished at the end of the month.

This is a lesson for the NASA community as it is troubling that this was discovered this way. Is there another way this could have been found? What are lessons learned for NASA mission in general? Those conversations were had with Jim Free and Pam Melroy. They rushed to get a notification out to industry as soon as they found out. By sharing information, they have been contacted by other organizations.

The vendor, Infineon, didn't contact you? They didn't know the exact environment where they would be used for the Europa Clipper mission as procurements took place several years ago. The factor is not age, it is the change in the company's manufacturing processes and this lost number specifically. They did not realize it would affect us but they are most certainly helping now.

What can be done better next time? Can the Office of Safety and Mission Assurance (OSMA) get better plugged in, so that it would know something like this is happening? It is

currently OSMA's highest priority. They are looking at what can be done better next time and how OSMA can get better plugged in. Right now, they are supporting the Clipper team while the Tiger Team addresses the risk.

Where was the point of failure? It was advertised to meet the specification, but they found out through the DoD that it would not. The team had no indication that they would receive MOSFETs that didn't meet requirements. It was stated to pass said requirements, but some may have come from the unusual lot that didn't meet the specifications. Infineon has since changed the manufacturing process so later lots are not impacted. As this has come to light, they have gone back and changed the process.

Is there any recourse with a vendor that sells a part that does not meet specs? Infineon thought it did meet specs since it met MILSPECS. They didn't realize it wouldn't work for the intense radiation environment. Procurement will need to weigh in.

The PSD responses to the PAC findings were discussed.

Finding 1, Support for Decadal Survey priorities and budget guidelines: The PSD thanks the PAC for this finding.

Finding 2, Thanks for Chang'e-5 samples access: The PSD thanks the PAC for this finding.

Finding 3, Science in Moon to Mars: NASA currently engages across several mission directorates, through regular boards that are focused on science and utilization. These boards draft science needs that lead to the definition of system requirements. Each of these boards is co-chaired by, or have polling membership from, all four mission directorates (SMD, ESDMD, Space Operations Mission Directorate (SOMD), Space Technology Mission Directorate (STMD)), to ensure science needs are met by the proposed implementation and execution paths and are factored into technology development investments. These boards apply at both the strategy and execution branches of the exploration programs. The ESDMD Deputy Association Administrator (DAA) for Strategy and Architecture and the Chief Exploration Scientist will attend this PAC meeting to talk through these processes. In addition, NASA continues to regularly solicit input from the science and technology communities through a variety of activities, including Lunar Surface Science Workshops, Lunar Exploration Analysis Group (LEAG)/Mars Exploration Analysis Group (MEPAG) studies, Lunar Surface Innovation Consortium (LSIC) focus groups, community studies/reports, and input to the annual Architecture Definition Document.

Finding 4, Deep Space Network (DSN) Maintenance and Expanded Capabilities: PSD recognizes and shares the PAC's concerns regarding DSN maintenance, capabilities, and bandwidth, and thanks the PAC for their recommendation. SMD has assigned a point of contact (POC) from the DAA office to collaboratively work with DSN to enhance communication and work through specific concerns related to SMD missions. As part of this enhanced collaboration with DSN, SMD has also created a Space Communications and Navigation (SCaN) Working Group and a Spectrum Working Group, which includes representatives from each SMD

Division. These working groups meet regularly to work through the details of mission specific concerns that are then brought forth to SCaN via the SMD POC. Additionally, SMD is increasing the rigor and frequency of dialogue pertaining to DSN maintenance and capability concerns that could affect the missions at the monthly Flight Program Review (FPR), as well as instituting a new review section required at each Key Decision Point (KDP)-C, specific to SCaN/DSN details for each mission. SCaN/DSN representatives are in attendance for those discussions at KDP-C.

Specifically for PSD, they have assigned the same Program Executive to both the SCaN Working Group and the Spectrum Working Group, and now require all mission Program Executives to engage in early and frequent discussions with SCaN/DSN. At the Agency level, a DSN Tiger Team has been created, with the SMD SCaN POC as an active member. This team meets weekly to work through DSN maintenance and capabilities issues, along with bandwidth and prioritization issues that could impact future support from DSN for SMD missions, as well as potential impacts and conflict resolution for Artemis DSN usage. This team reports directly to the SOMD Associate Administrator (AA) at the quarterly SCaN Board of Directors, which SMD's AA co-chairs with the SOMD AA.

As a result of the Agency and SMD enhanced collaboration with SCaN/DSN, we are seeing issues being resolved and future planning is more detailed and accurate. A unified voice, from SMD and SOMD, is also better communicating the need for additional funding for SCaN to senior Agency leadership. PSD is optimistic that the increased spotlight on DSN issues to senior Agency leadership will result in fruitful changes and risk mitigation for our SMD and Planetary missions.

Finding 5, Thanks to Exoplanet Analysis Group (ExoPAG): PSD thanks the PAC for this finding.

Dr. Grant asked about the termination review of VIPER and requested clarification. As a top-level summary, the project was overrunning in terms of their development costs, which triggered a review. A 30% over run, approximately \$100M – at the rover at Ames. It could end up launching or being terminated within six months of their potential launch.

Inclusion, Diversity, Equity, and Accessibility Cross-Analysis Group Working Group

Dr. Julie Rathbun, chair, was introduced to present for the Inclusion, Diversity, Equity and Accessibility (IDEA) Cross-Analysis Group (XAG) Working Group. She thanked the PAC for the invitation and the PAC's long-term support.

She discussed the [link](#) that allowed visitors to view which Native American groups are in their particular location as everyone is on the unceded lands of dozens, if not hundreds, of Native American peoples. It is a good first step, the website, but it is only a first step and more must follow.

Dr. Rathbun discussed the current XAG work in progress includes deconflicting meetings; hosting an upcoming 2-day AG style meeting; breaking down the National Academies of Sciences, Engineering, and Medicine (NASEM) study; inclusion plans; and tasks for an outward facing EDIA position within NASA. She also covered items focused on amplifying the

community and grassroots EDIA efforts including an IDEA conference; focusing on mental health; working with Dr. Aster Cowart following the Lunar and Planetary Science Conference (LPSC) 2024 regarding the Trans experience; trying to establish an Office of Tribal Relations; and speaker series for their monthly meetings.

Dr. Rathbun applauded the EDIA actions NASA is taking including: deconflicting meetings and ROSES due dates from religious observances and affinity group meetings; funding the Topical Workshops, Symposiums, and Conferences (TWSC) for a 2-day-in-person meeting of the XAG EDIA WG; starting the development of an Inclusion Plan Rubric; supporting the IDEA Conference of 2024; and funding EDIA activities. They do ask for an update on the Mission: IDEA Research and Analysis (R&A) funding line mentioned to the PAC previously. She also wanted to amplify or co-sign some of the findings from other analysis groups that will be presented at a later time specifically the Small Bodies Assessment Group (SBAG) **Finding 10**.

She highlighted the IDEA AG's six recommendations:

Recommendation: Recommend that PAC designate one member explicitly as EDIA member and require expertise, parallel to NASEM study's recommendation regarding the NASA Advisory Council (NAC).

Recommendation: That the PAC ask NASA to report on progress in collecting demographics as recommended by both the NASEM study and the planetary decadal survey.

Recommendation: NASA should clarify that inclusion is not just making sure that the current team feels included but that the team should create a space where a person from any background would feel included.

Recommendation: NASA should allow Inclusion Plans to include funding for EDIA training and involvement in EDIA-related groups.

Recommendation: PAC raise to the NAC the recommendation that NASA establish an offer of Tribal relations, as reiterated in the Nature paper.

Recommendations: NASA should work with NAC to create a "Senior Scientist for SMD Workforce and Culture" and the PSD should continue to advocate for the position.

Dr. Ishii asked how creating an environment where anyone feels included would be actualized and what would be the budget implications associated with the effort? The practical things would be training and then looking at psychological safety within the workplace as a survey test. Training, discussions, and surveys would be the best way to go about that.

Dr. Ishii asked about the in-person AG meeting and its accessibility via remote? Yes, it will absolutely be hybrid with an online platform.

Mr. Barbee asked about the budget implications. There have been many, many studies that you get better science when you have a diverse and inclusive team. The more diverse your team is – the more science you get out of it. You are going to get better science with IDEA.

Dr. Jessup followed up with some thoughts on the budget associated with IDEA training. Who is asking for training and is it part of the inclusion plan or is it coming from the IDEA AG? Having training associated with onboarding or possibly available quarterly for NASA would be ideal. People need to be trained and incorporating it early means less effort on the backend. Dr. Ishii stated that it could be a good recommendation to add it to the pipeline supporting programs. A comment was made to ensure definitive verbiage was specific for IDEA training. Dr. Kiefer questioned the possible recommendation and its focus on individual teams or specific to the missions themselves.

Mars Exploration Program

Dr. Eric Ianson, the MEP Director, was introduced along with Dr. Mitch Schulte, the MEP Acting Lead Scientist. Dr. Ianson described the MEP highlights which include NASA and ESA signing a MOU for ESA's Rosalind Franklin Mission; Odyssey completed 10,000 orbits around Mars; concept studies have been awarded to industry to investigate how commercial services can be utilized for mission to Mars; and solar maximum activity is generating excellent opportunities to study space weather at Mars. He introduced new MEP HQ staff.

Dr. Ianson discussed the MEP budget. The PBR was released March 11, 2024. The MEP is currently operating under the Fiscal Responsibilities Act through FY2025. They are operating missions as the funds allow all missions to continue but the MAVEN funding ends in FY26. Sample Receiving Project (SRP) funding may be reduced pending the decisions on the MSR architecture. The Rosalind Frankling Mission funding supports a 2028 and the MEP Technology Program was boosted in FY24. As far as the planning, programming, budgeting, and execution (PPBE) process for FY26 – it is underway. They are considering options to restore MAVEN funding beyond FY26 and there is a plan for a senior review regarding the results of operating missions.

The commercial and technology activities were reviewed. They awarded commercial studies to nine companies to assess the cost, feasibility, and technological maturity for Mars science enabling services. The Future Plan technology strategy is being worked on to address future needs. MEP is also planning near-term technology efforts in anticipation of the \$40M increase in the FY25 technology budget.

Several upcoming activities were highlighted including the creation of a Search for Life Science Analysis Group (SFL-SAG); the 10th International Conference on Mars in Pasadena, California date for July 22-25, 2024; and the Science and Planetary Protection in Advance of Human Exploration Virtual Seminar and Virtual Workshop happening July 31-August 1 and October 15-17, 2024. Dr. Ianson discussed the MEP pre-formulation efforts which include the NASA Rosalind Frankling Mission Project and the SRP.

Dr. Schulte discussed Mars 2020 and how much ground Perseverance has covered, the Margin Unit Campaign, the MSL Curiosity, the MEP Orbiter science of the Mars Reconnaissance Orbiter (MRO) and Odyssey, and the recent solar activity at Mars.

Dr. Ishii asked what are the options of MAVEN's funding after FY26 and what are the considerations? Given the anticipated budget restraints, this budget assumes it will complete its

mission objectives by FY26, NASA will reassess the mission status in future years. They are in the middle of the budget process so they can't talk about specifics. They know MAVEN is producing. They value the science. They anticipate it will do fairly well in the review process. We certainly view it as a priority in our budget process.

Senior review is contingent upon producing good science. How does MAVEN's status as a relay asset fit into all of this? All of that will factor into our process. It is a valuable mission, and we want to figure out ways to continue to keep the mission operating.

Dr. Curry wanted to get a better understanding of Mars 2020 going into a quiet mode in the near future and how science will be retained? They will continue doing mission operations and science, we will just be reviewing how and when that science is done. Dr. Schulte stated that there are some bigger issues, but it is important to continue doing science, even if they have the rover go to a specific spot and wait. Dr. Ianson stated that they had made any decisions about it.

Dr. Cable asked about the plan for the five aging orbital assets/missions out at Mars? The Mars Future Plan is related to infrastructure and the number one priority is the Mars Relay Network. We will continue to keep a robust relay network available to us as our existing assets age. It is an international concern and other organizations potentially can help them keep the Mars Network up.

Dr. Murrow asked a follow-up question regarding the commercial relay networks – where is the thinking regarding commercial missions? They don't think they are in a good position as it relates to understanding the full width and breadth of commercial services, which is why they were doing the study. They need a little more time to figure that out.

Dr. Grant asked about the funding level of the missions. They are still in their budget process so can't speak specifically about any of them. They take all missions and input very seriously, evaluating key priorities for those missions. They cannot discuss absolutes right now.

Dr. Grant asked about there is any word on if there will be a participating science call on Rosalind or Mars 2020? All of that would be budget dependent and is being considered.

How much of the MEP budget is part of the SRP? It is small because the FY budget number is \$500K. Very contingent upon what MSR has going forward.

Dr. Ishii asked about the study agreement between ESA and NASA? It is a fairly broad study agreement on how they would handle samples and safety assessment. Because of the state of MSR currently, they want to keep the communication open. The study agreement allows for data exchange and future analysis.

Dr. Ishii was wondering if there was any concern about Congress looking at the studies from the commercial parties. Is there a worry that they will think that they will wait? That may be best answered by the MSR folks.

Dr. Murrow asked how MEP and Mars 2020 are supporting the architecture programs with MSR? MEP and MSR programs are organizationally independent, but they are located right next to each other. They tag up frequently for communication and groups. If they are unable to

resolve a dispute, they bring it up to Dr. Fox. However, they have not had to do that because they work in close alignment.

Dr. Murrow asked how MEP is supporting the Agency level M2Ms architecture? They are working with M2M folks. They are discussing science as it relates to human exploration. At the last MEPAG, there was conversation about Lunar surface science and that they wish to do that with Mars.

Are the workshops going to be influenced by the academy study? They look at things holistically, so as new information comes in – they take it all into account.

Dr Ishii summarized some of the information and questions that the PAC currently had at this point in the meeting which included the intersection between M2M and MSR; the possible finding of maintaining continuity in the Mars 2020 team; and then the possible finding with no recommendation of the support of the early career awards.

DSN Usage Update

Mr. Philip Baldwin, Deputy Program Manager – Operations of SCaN, was introduced. SCaN is the essential connection to the human explorers, the science missions, and the partners. He discussed the focal points for NASA SCaN and how SCaN serves as the enterprise responsible for all of NASA's space communication activities. He provided a chart of NASA's communication networks.

SCaN's DSN role and structure was discussed. DSN is the only US network dedicated to providing telecommunications services for missions in deep space. DSN also supports international spacecraft and scientific investigations. DSN has three complexes, spread across the world to ensure 24/7 coverage. On behalf of SCaN, the NASA JPL develops, operates, and manages DSN. Mr. Baldwin discussed how deep space communications are key to the Agency's priorities.

The DSN has a major challenge as it is rapidly growing with user needs. The cadence and complexity of cis-lunar and SMD missions are creating a new level of network demand not seen in decades. To combat this, DSN is building capacity with the DSN Aperture Enhancement Project (DAEP), enhancing capabilities with the DSN Lunar Exploration Upgrades (DLEU), adding support with the Lunar Exploration Ground Sites (LEGS), and by increasing efficiency with Multiple Spacecraft per Aperture (MSPA) and Ka-band. The use of MSPA and Ka-band on future missions will reduce DSN load and enhance performance for individual missions as well as the network.

The DSN is working on its reliability, robustness, and resilience. The Artemis outage was discussed. Applying lessons learned from JWST and Artemis 1 scheduling and prioritization techniques will also be key to SCaN's future approaches in support of planetary missions. They want NASA to collaborate with them to generate a robust scheduling process, as well as clear articulation of mission needs and preferences, to enable more dynamic schedule support in the era of human spaceflight. The DSN is exploring optical options. NASA has successfully

completed extensive optical demonstrations. Operationalization needs to be driven by mission community.

Mr. Baldwin stated that if SCaN is successful, then so is NASA. The growing DSN demand is causing challenges to meeting science and exploration mission needs. SCaN is working to enhance the capabilities, capacities, and efficiency of the DSN. Major sustainment investments in the DSN are also helping improve reliability, robustness, and resiliency. They need assistance with scheduling and prioritization on a collaborative basis and that future missions use Ka-band and explore other mission efficiencies maximizing throughput.

Dr. Ishii asked if all of the efforts described would fix the DSN issue? No, it would not fix the issue – it would help the issue.

Dr. Cable asked if there were any suggestions or offers to incentivize persons to use Ka-band or optical means? They looked at shared-cost models, test models, and bought down a significant amount of risk for these options.

Mr. Barbee asked about plans to mitigate the demand on the network? They've worked with the M2M Program to ensure that vendors are using meters not associated with the DSN. That has helped with the curve. As vendors come on board, they are driving them to use smaller apertures. Despite all of that, the DSN needs more capacity.

Dr. Prockter asked when do the LEGS come on? 2027, if they are not mistaken. With less than a year between the next ones. Mr. Barbee made the point that you can't keep others from using the system and taking up some of the capacity.

Dr. Prockter asked how they prioritize missions and how do they know the longevity of the missions? They are working on prioritization and scheduling, but they prioritize NASA currently. It is being looked at now between the multi-directorates. As far as longevity of a mission, they use what is predicted and give a little leeway. They keep up with the missions along the way. It has some challenges. For example, six antenna rays are facing Voyager 1.

Dr. Woods asked the PAC how they could support and advocate for the DSN and Mr. Barbee asked if there was anything that the DSN needed. Having support and advocacy, is key as preventative maintenance is a lot. You either have to complete maintenance or build new and they can't afford to do both at the same time without dropping the ball on missions.

Dr. Murrow asked how much deferred maintenance is there to buy down? Is it a billion or 10 million dollars? It is about \$40M a year, with a \$10-20M that we get back – leaving \$20M short.

Dr. Jessup asked if there is real choice in optical as far as infrastructure and such? There are some things that need to be done with optical. It doesn't help with the maintenance shortfall, but it does help with capacity. It is a different trade between maintenance and building up optical. They are looking at cross links with optical and trunk links. They are looking on how to move forward on all of that.

Mr. Barbee asked about the better need for scheduling and the need for a collaborative tool or is this something that is being worked? JPL takes the lead on scheduling, but it is not a singular system. There are scheduling teams that coordinate back. They have a tool that they all collaborate on and discuss. They are trying to increase the automation pieces to make it more efficient and dynamic. JPL had to make adjustments on nights and weekends, late and on the fly, to meet mission needs.

Mr. Barbee asked about the best way to get the word out about SCA_N and the DSN? Having some forethought on how you use comm is key. One mission takes double the passes because of comm reliability, that is challenging. Lunar surface, 24/7 for not having automation at the mission. The ConOps greatly impacts the use of the DSN. Considering decisions that they hadn't thought about before when it comes to 24/7 communication.

Public Comment Period

Dr. Ishii opened the public comment period.

The only submitted chat question/comment was: *What processes determine what missions receive funding going forward? I'm asking specifically about MAVEN which the budget is currently zeroed out for in 2027. To my knowledge, MAVEN is very fruitful from a scientific standpoint. What factors are taken into account in this process?* Dr. Braccio stated that there is a budget perspective and a Senior Review Process that has a role in this to make decisions.

PAC Discussion

Dr. Ishii led the PAC in discussion regarding multiple topics including SCA_N, ground-based observations, VIPER, the PBR 2025, New Frontiers and Discovery A&O, OSIRIS Rex, Early Career Awards, M2M, and potential findings.

July 10, 2024

Moon to Mars Architecture

Ms. Julie Grantier, Deputy Manager for Integration, and Dr. Jacob Bleacher, Chief Exploration Scientist, were introduced. Dr. Bleacher discussed the ESDMD organization chart. He discussed the seasonal cycle of the Lunar Draconic Year at the South Pole of the moon.

Dr. Bleacher highlighted science, inspiration, and national posture of the M2M objectives. For inspiration, accepting audacious challenges motivates current and future generations to contribute to voyage deeper into space. For science, investigations in deep space, on the Moon, and on Mars will enhance our understanding of the universe. For national posture, what is done, how it is accomplished, and who participates affects the world, quality of life, and humanity's future. They needed an objective-based approach as they must think strategically with resilience and flexibility in mind and enhance their communications to better achieve unity of purpose.

NASA's M2M Objectives document a systems engineering approach to crewed deep space exploration. In contrast to a capabilities-based approach, an objectives-based approach focuses on the big picture, the "what" and "why," before prescribing the "how." The methodology for the M2M Objectives is guided by five interrelated principles: objectives-based approach, constancy of purpose, enhanced communication and engagement, unity of purpose, and architecting from the right while executing from the left.

Dr. Bleacher touched on recurring tenets that include international collaboration, crew time, interoperability, industry collaboration, maintainability and reuse, leverage LEO, crew return, responsible use, and commerce and space development. He also discussed the science objectives which include Lunar/Planetary science, physics and physical science, Heliophysics science, science-enabling, human and biological science, and applied science. NASA requested feedback on these objectives in the summer of 2022 from the following key stakeholders: NASA workforce, international partners, the United States (US) industry, and academia.

Ms. Grantier discussed the evolutionary architecture processes, which is the formulation of an architecture and exploration strategy based on objectives. This included traceability, architecture framework, and processes and products with clear communication and review. She explained the concept of architecting from the right, while executing from the left. The process of "architecting from the right" decomposes M2M Objectives into element functions and mission use cases. This establishes the relationship of executing programs and projects to the driving goals and objectives. Segments, sub-architectures, and elements are architectural components. The segments of the architecture include the Human Lunar return, foundational exploration, sustained lunar evolution, leading to humans on Mars.

She highlighted sub-architectures including communications, navigation, positioning, and timing systems; habitation systems; human systems; logistics systems; mobility systems; power systems; transportation systems; and utilization systems. To empower partnerships, the M2M architecture products enable strategic conversations where NASA's needs and partner strategies

align. She discussed the partner pre-formulation process that focuses on element initiation, mission concept reviews, and acquisition strategies. In 2024, NASA began analyses needed to allow for informed decision-making by Agency leadership, beginning with the seven priority decisions identified. Decisions for Mars will inform lunar planning, development, and needs to demonstrate and ready systems and operations for eventual Human to Mars segment missions. She touched on architecture products including White Papers.

Dr. Bleacher addressed the Artemis I science payloads. Science and technology investigations and demonstrations are paving the way for future, deep space human exploration. They have announced the Artemis II crew which will test out Orion. For Artemis III, NASA has chosen the first science instruments designed for astronauts to deploy on the surface of the Moon. Once installed near the lunar South Pole, the three instruments will collect valuable scientific data about the lunar environment, the lunar interior, and how to sustain a long-duration human presence on the Moon. Additionally, NASA will conduct integrated, crewed science on the lunar surface and collect at least one sample.

He discussed Gateway partnerships and science instruments. Gateway's polar orbit will offer unique opportunities for Heliophysics, human health research, space biology and life sciences, astrophysics, and fundamental physics investigations. As new modules are added, science capability will increase.

Dr. Ishii asked for clarification between the M2M and the strategy and architecture office, the strategy and architecture office is "calling the shots." Dr. Bleacher stated that they are communicating and strategizing, the M2M Program Office implements the mission. The whole architecture review is annual, in November. Then workshops will be held in February. Everyone of the directorates is involved, real-time, in the analysis cycle throughout the year.

Dr. Grant asked about the architecture and the building of the objectives within the timeframe – and the Mars decisions. Dr. Bleacher discussed the loop that they've had regarding what they want to do and how they want to do it. They spent time developing strategies.

Artemis Science Planning

Dr. Cynthia Evans, Artemis Geology Training Lead, was introduced. Crew training in geology, including lunar science and field methods, is a critical step for successful Artemis missions. They have provided an overview of the training conducted over the past year and have discussed future geology training for Artemis crew. The bottom line is that NASA is now providing training in geology and lunar science to astronauts assigned to Artemis missions, as well as Artemis Flight Controllers. The crew training is a cross-agency and multi-institutional effort. Artemis planetary science will be achieved through lunar surface traverses. They have been building plans, developing relationships, and delivering geology training to the crew office and the exploration community for over fifteen years.

There are three basic phases of astronaut training. The initial training phase provides them with a foundation, secondary phase focused on building and maintaining skills, and the tertiary phase associated with the mission science training. Phase one establishes the base of geology, field methods, introduction to the importance of sample curation, and the overview of

NASA's planetary science. This phase includes six field days in Northern Arizona, with a capstone exercise. Phase two is building and maintaining skills. This phase includes lunar fundamentals and lunar integrated testing along with proficiency training. Phase three is assigned crew training. Artemis II was the first opportunity since Apollo for humans to directly observe and document the Moon from lunar orbit.

NASA has been providing geology and field training to the Astronaut Office continuously for more than fifteen years. All astronaut classes since 2009 have received basic geology and field training. They have regular opportunities to pull crew members into additional field expeditions and testing scenarios with science operations. They are actively training the Artemis II crew for their observation of the Moon. They are steadily filling in the geology and planetary science training "heat map" for the NASA human space flight (HSF) and exploration community.

Dr. Barbara Cohen, Sample Integrity Lead, was introduced to review PAC questions associated with Artemis samples. The primary goal of Artemis EVA science is to explore, document, and gain understanding of the field site. This activity enables real-time confirmation or refutation of hypotheses formed on the ground, which in turn guides science activities such as imaging, sampling, and instrument deployment. A thoughtfully planned, skillfully collected, carefully returned, and meticulously curated set of samples from each Artemis mission will be crucial for addressing Decadal-level and Artemis III Science Definition Team (SDT)-prioritized science goals in the lunar south polar region. Field testing and science team training incorporate, test, and refine sampling protocols including active mass management, tool utilization, time allocation for tool use and sample collection, etc.

Sample collection is part of a well-orchestrated field campaign, guided by hypotheses and science utility in addition to practical considerations such as mass and sample type. The Artemis III full science team are developing the science requirements and a sampling plan for the selected sites that fits the science and utilization constraints. An optimal SRP is built upon geologic-context observations made by well-trained astronauts, aided by modern tools and real-time communication with scientists on Earth. Minimizing contamination at every stage via materials selection and processes is part of carefully returning the samples. They are developing requirements for Sample Integrity and cleanliness. Sample curation planning and implementation go hand-in-hand. The Artemis Curation Lead and the Lunar Sample Curator work closely together on all relevant aspects of Artemis program and missions.

The Advanced Information Systems Technology (AIST) continues to stay engaged in hardware developments to ensure science considerations are incorporated early and often. The EVA and Human Surface Mobility Program, approved in January 2022, manages Artemis EVA hardware. The Exploration EVA (xEVA) element includes the spacesuit and tools required for lunar science during all surface missions, while the LTV and PR elements will provide long-ranged EVA mobility and telerobotic capability as Artemis missions progress. Artemis III architecture assumptions are extremely limited for achieving mission science goals and are inadequate for a robust sample return program. The Human Explorations and Operations Mission Directorate (HEOMD) recognizes that landed missions during the "sustainable" phase of

Artemis needs to have increased capabilities. The SMD is advocating to use these increased capabilities for improving the SRP including increased sample returned mass and volumes for use during the landed mission and to help with other aspects of return; increased tool capability; increased area of sample collection; and improved environmental conditioning capabilities.

Analysis Group (AG) Reports

Dr. Ishii gave instructions to the AG presenters prior to the start of this section.

Mars Exploration Analysis Group

Dr. Vicky Hamilton, chair of the MEPAG, presented the MEPAG update. The *Connecting Community Scientific Hypotheses to Mars Sample Science* workshop convened jointly with the Extraterrestrial Materials Analysis Group (ExMAG). MEPAG #41 was held in Washington DC.

The MEPAG reaffirms its support for the solar system-wide science of MSR as the top priority for the Mars program in the first Planetary Decadal report from 2003 and the top priority overall of the last two Planetary Science Decadal Surveys and concurs with the most recent Decadal recommendations that: (1) MSR be executed as soon as practicable with no increase or decrease in scientific scope, and (2) if the cost is greater than the value or budget fraction adopted in the Planetary Decadal Survey report, the Administration work with Congress to secure the budget needed to ensure the success of this strategic mission. MEPAG commends the MSR MIRT for their hard work and thoughtful deliberations in responding to the IRB-2 report and developing a proposed path forward for MSR. MEPAG understands the need for NASA to find an acceptable architecture, schedule, and cost for MSR and welcomes NASA leadership's continuing affirmation of the Agency's support for the tremendous scientific advances that MSR will enable in understand the Solar System's origin and evolution.

MEPAG strongly supports NASA's stated intent to independently assess the science, cost, schedule, capability, and risk posture associated with the results of the mission design studies; the stated intention to receive study reports by October and announce plans forward in early 2025 will help to avoid further delays to progress on the Mars 2020/Perseverance and MSR missions and the SRP. MEPAG reaffirms that science must be a driving priority for MSR and therefore strongly supports NASA's stated intent to evaluate the results of funded mission design studies on the diversity and number of samples they enable to be returned. As NASA evaluates the best path forward for MSR, MEPAG urges NASA to maintain key capabilities of the specialized and world-leading US workforce at NASA Centers and industry partners, including unique capabilities for landing on Mars and Martian surface operations. This will enable NASA to conduct MSR and future exploration missions in a manner that sustains US global leadership and international partnerships.

MEPAG concurs with the MIRT's of the importance of: (1) returning the greatest number of samples possible and encouraging M2020 to expand the quality and diversity of the return sample suite by driving Perseverance up and out of Jezero Crater to access strata from earlier in Mars history and formed by different geologic processes, as well as (2) science being conducted by perseverance along its traverse, which provides critical regional context for the samples and

further aids the understanding of Mars through in situ exploration. MEPAG reaffirms that the cache presently on the Perseverance rover is scientifically superior to the contingency cache deposited at Three Forks because it contains more diverse and higher quality samples; collection of additional samples will further increase the scientific value of the rover cache. To ensure the maximum science return is enabled by any revised MSR mission design, multiple members of the MEPAG science community, particularly those with mission implementation experience, should be fully involved in the evaluation of mission designs, and decision making having an influence on the science return of MSR. This should be an active, ongoing dialogue: close partnerships between scientists and engineers as one evaluation team will provide the best chance for your identifying architecture solutions that maximize science return while minimizing cost, schedule, and risk.

The Ingenuity helicopter is a successful example of a higher, but considered, risk posture approach that may provide a means of realizing additional cost savings for the class of small, low-cost science missions at Mars envisioned in the forthcoming SMD/MEP Mars future plan. MEPAG Excited to see a substantial investment in Mars technology development and looks forward to contributing to determining priorities for that work, e.g., as outlined in the Mars Concurrent Exploration Science Analysis Group (MCE-SAG) report. MEPAG seeks to enhance collaboration with the astrobiology community, including through Research Coordination Networks (RCN), with enhanced Mars astrobiology focus, and looks forward to further interaction through mechanisms such as the upcoming Search For Life Science Analysis Group (SFL-SAG). MEPAG encourages SMD and ESDMD to continue identifying pathways for regular communication between the M2M architecture team and the Mars science community to incorporate science input into decisions that guide the architecture. Towards this goal, the MEPAG community expressed its strong support for initiating a series of human exploration related workshops.

Extraterrestrial Materials Analysis Group

Dr. Philipp Heck, chair of the ExMAG, presented the update. Dr. Heck thanked the steering committee (SC) and presented an organization chart. Recent accomplishments and upcoming events including the ExMAG Special Poster Session at LPSC on Sample Science Facilities and Collections, the ExMAG Annual Public Meeting, and the joint MEPAG-ExMAG Workshop.

Finding 1: To ensure broad accessibility, the ExMAG strongly advocates for NASA to maintain and expand opportunities for the Astromaterials community to receive training on how to use AstroMat. They appreciate NASA's ongoing commitment to facilitate the implementation of Space Policy Directive (SPD) 41, including the AstroMat project, which aims to enhance open access to planetary sample data through training, tutorials, and tools to facilitate data management. Additionally, ExMAG encourages collaborative efforts to promote interoperability between AstroMat, Curation catalogs, and other NASA-funded databases.

Finding 2: ExMAG urges NASA to continue working with the National Science Foundation (NSF) or search for other options to ensure logistical support of the Antarctic Search for Meteorites Program (ANSMET). ExMAG recognizes the importance of the ANSMET program that provides crucial samples to the community. The recent NSF decision to halt support for the 2024-2025 ANSMET season raises significant concerns, particularly with increased snowfall potentially burying critical field areas. ExMAG acknowledges NASA's efforts in finding a solution. They are committed to supporting these efforts. ExMAG commits to providing NASA with compelling evidence for continuation of the program, such as highlighting the groundbreaking science derived from ANSMET samples. If reengaging NSF fails, ExMAG encourages NASA to explore alternative logistic support for ANSMET, including international collaborations, to ensure ANSMET's continuity.

Finding 3: ExMAG appreciates NASA's effort in supporting US-based scientists' access to Chang'e-5 samples. The Chang'e-5 sampling site differs from sites sampled during Apollo and its samples have proven to hold new information about the Moon's history. ExMAG applauds the remarkable achievement by NASA in finding avenues for US-based scientists to access Chang'e-5 samples. While loan agreements are still being negotiated, ExMAG supports NASA's continued endeavors to find a solution.

Finding 4: ExMAG commends NASA's and ESA's effort in finding a viable path forward for MSR and urges NASA to continue to support the next generation of scientists and the upcoming MMX mission. Martian rocks collected by Mars 2020, unlike any current meteorite collections, hold unique geological context thanks to detailed orbital and lander measurements. This context is crucial for understanding Martian evolution. Studying these examples, including their ages and composition, will unlock new discoveries about Mars and the Solar System, benefiting the broader scientific community. ExMAG recognizes the technical complexity and cost challenges of MSR. They commend NASA's efforts to find a viable path forward and strongly encourage continued support for MSR within its future plans. The potential delay of MSR underscores the importance of training the next generation of scientists. Furthermore, ExMAG advocates for continued support of the upcoming MMX, which presents the first chance to potential return Martian samples.

Finding 5: ExMAG urges NASA to expand its support for training opportunities in sample handling and analysis, particularly for early career researchers. The high demand for training programs underscores the critical need for such inclusive opportunities. To ensure inclusivity and address oversubscription, ExMAG proposes exploring additional avenues and increasing support for existing opportunities. This could involve partnering with new institutions, expanding the range of training topics, and considering alternative delivery methods. Given the successful record of sample handling workshops, ExMAG encourages NASA to provide funding avenues that support more widespread involvement by advanced researchers to interact with early career researchers. For example, short project funding grants or workshop grants could be used to cross-pollinate ideas across the community.

Finding 6: ExMAG recognizes the unique environment of the Lunar Gateway and the opportunities it could provide for cosmic dust collection. The NASA Gateway presents a

groundbreaking opportunity for collecting cosmic dust in its pristine lunar orbit. While return of collected dust awaits the Canadian robotic arm's installations in the 2030s, collection can begin much sooner. The first Gateway element launch, targeted for 2025-2026, will enable the direct collection of dust and measurement of dust flux in an environment free of orbital debris. This would be followed by an in-situ mass spectrometry mission in the early 2030s, allowing the analysis of the composition of interstellar and interplanetary dust. By capitalizing on these initial Gateway opportunities, they can unlock its full potential for cosmic dust science and pave the way for future sample return missions. ExMAG urges NASA leadership to prioritize these early dust collection endeavors, recognizing their high scientific value and significant return on investment.

Finding 7: ExMAG calls on NASA to prioritize research and development (R&D) efforts in cryogenic sample collect, handling, storage, and analysis. The LEAG-ExMAG SAT team has identified a critical knowledge gap in these areas, particularly for the preparation and analysis of samples collected from lunar cold traps. Understanding the origin of volatiles in the inner solar system is a key knowledge gap identified in the decadal survey, and analyzing icy samples from these cold traps is essential for this research. However, they must invest in upgrading equipment to collect, handle, store, and analyze these cold and volatile-rich samples without compromising their scientific value. To address this technology gap and pave the way for future cold trap sampling missions, ExMAG urges NASA to invest in R&D focused on developing cold to cryogenic technologies specifically designed for the analysis of returned cold-curated and volatile-rich lunar samples.

Finding 8: ExMAG commends NASA, the OSIRIS-REx mission team, and the Astromaterials Acquisition and Curation Office at JSC on the successful return and distribution of samples from asteroid Bennu. The successful return and distribution of samples from asteroid Bennu to the OSIRIS-REx mission team and opening of the first sample request to the community is highly impressive. ExMAG thanks the curation team at ARES JSC for cataloging and preserving these invaluable samples. ExMAG recognizes the challenges the curation team faced in opening the sample return canister and commends the Astromaterials Acquisition and Curation Office at JSC on their tireless efforts and dedication to successfully preserving the integrity of the OSIRIS-REx samples.

Outer Planets Assessment Group

Dr. Amanda Hendrix, Outer Planets Assessment Group (OPAG) chair, presented the OPAG update. She discussed findings from the June 2024 OPAG community meeting.

Finding 1: (A) OPAG strongly supports NASA's current plan to provide a community announcement describing NF5 AO parameters in the October to December of 2024 time frame, which is 18 months ahead of the planned AO release and Q3 FY26. Proposal teams require expected AO parameters to conduct trade studies and design their mission concepts, and it is critical, in the interest of the community, for NASA to stick to the announced schedule without further delays. (B) OPAG Strongly supports the decision to have the Committee on Astrobiology and Planetary Sciences (CAPS) revisit the NF5 target list due to the multiple delays in the AO and due to new developments since the Decadal Survey. The outer planets targets are all

exceedingly compelling targets. They note that the OPAG urges consideration of Triton for the NF5 list considering the developments since the last Decadal Survey that demonstrate multiple feasible launch opportunities over the expected NF5 launch window. This new development, combined with the unavoidable timing lag in NF6 and NF7 makes NF5 an important opportunity for this mission target. A Triton mission concept was placed on the NF7 list solely based on the assumption that a trajectory would only be achievable in the then-presumed NF7 timeframe, but the schedule delays have invalidated this assumption. OPAG urges NASA to include Triton, along with the other out planets targets, on the NF5 list – in line with the Decadal Survey intentions.

Finding 2: OPAG appreciates that the FY25 PBR includes funding to begin formulation studies for the UOP mission in FY27. OPAG strongly encourages NASA to commit to starting these activities in FY27, as planned, to be consistent with Decadal Survey recommendations, and given that the science return can be maximized by arrival at Uranus as close to the equinox as possible. Formation and support of a core science team no later than FY27 would support the timely refinement and prioritization of UOP science objectives that would drive any required focused formulation studies for this already well-studied mission.

Finding 3: OPAG thanks NASA and the RPS Program from their continuing efforts to prepare RPSs that are critical for high priority future missions without alternatives, especially for outer planets missions, including UOP. OPAG requests NASA to assess the readiness and performance metrics of NGRTGs, and potentially make this capability available for technology infusion on missions launching after 2030.

Finding 4: OPAG requests that NASA prioritize resources to observe the upcoming stellar occultations by Uranus on April 8, 2025, February 15, 2031, October 9, 2031, and February 6, 2032. An exceptionally bright star is occulted on February 15, 2031, enabling a once-in-a-century opportunity to measure the Uranian upper atmosphere from Earth. Stellar occultation measurements sense altitudes that are important to future aerocapture vehicles and atmospheric entry probes, and thus these measurements could reduce risks to future missions, in addition to delivering valuable scientific knowledge about the upper atmosphere of Uranus and its rings.

Finding 5: OPAG emphasizes the importance of the Hubble Space Telescope (HST) as an asset for critical solar system science observations. OPAG is concerned about the severe cuts in funding for HST users in recent observing cycles. OPAG requests that PSD look into the appropriate solution to adequately support HST data analysis, perhaps by allowing ROSES proposals to more liberally allow use of HST data than currently, including allowing the use of archival data.

Finding 6: Given current plans to produce super heavy lift launch vehicles at a cadence likely faster than they will be used, OPAG encourages NASA to study use of these potentially very enabling capabilities for planetary purposes including UOP. OPAG requests that NASA work to make available its assessment of super heavy launch vehicle offerings by NASA and

industry and anticipated costs to SMD on a timeline that would allow them to be considered for future PSD missions and report the findings to OPAG at the 2025 meeting.

Dr. Hendrix then addressed the statements of support and concern from the June 2024 OPAG community meeting.

OPAG continues to strongly endorse Europa Clipper as it prepares to launch in October 2024. They also congratulate the Dragonfly team on their mission confirmation and are particularly grateful for the supportive coordination between the Dragonfly mission team and NASA for moving the mission forward in this challenging budget environment. OPAG additionally supports ongoing missions in the outer solar system and recognizes the outstanding science return of missions such as JUICE, Europa Clipper, Juno, New Horizons, and Voyager 1 & 2, in the past, present, and future. OPAG is concerned, however, that two US contributed instruments on JUICE still have unfunded co-investigators.

OPAG recognizes the scientific benefits of exploring the broader Jovian system with Europa Clipper and taking advantage of cruise opportunities. They additionally support the JUICE-Clipper SC investigation of joint activities that is identifying opportunistic science measurements and assessing their potential impacts and feasibility. OPAG encourages NASA to implement a mechanism to allow for such observations and to add science team members to plan and conduct investigations during Clipper's approach to the Jupiter System.

OPAG supports the development of a joint Code of Conduct (CoC) for the AGs, by the XAG-EDIA with collaboration from OPAG, and other AGs. They applaud NASA's steps to improve inclusion in funded work through the ROSES Inclusion Plan Pilot Program. These steps are essential to attracting and retaining the best talent, and for ensuring safe and productive work environments. In defining team member roles of proposed inclusion efforts, many groups draft team CoC. Similarly, such codes have proliferated among conference organizations and mission teams, in efforts to prevent and respond to personal and research misconduct. Having a uniform code of conduct for the AGs would clarify expected behaviors, making it easier to respond appropriately to misconduct when it occurs. Furthermore, OPAG supports a NASA effort toward a unified CoC or guidelines for Ethical Conduct for NASA sponsored activities, while the aim of streamlining the implementation and enforcement of inclusion plans.

Discovery missions could enable focused science investigations at Outer Planets targets, as indicated by past Discovery proposal submissions. For some of these concepts, RPS technology could be enabling. During the NASA PSD update, Dr. Ianson stated that there will not be a Discovery AO in the next two years. OPAG eagerly awaits finer details on the upcoming Discovery AO plans and guidelines, and requests that NASA consider making RPS technology available for Discovery mission concepts, which in turn would factor into NASA's RPS development plans over the next decade.

The Origins, Worlds, and Life (OWL) Decadal Survey recommended that NASA develop scientific exploration strategies for areas of broad scientific importance – including ocean worlds explicitly – that have an increasing number of US missions and international collaboration activities. Scientific exploration strategies examples to be considered included (1) coordination

within NASA to support key research topics encompassing remote sensing, laboratory, theoretical, and ground-based telescopic investigations focused on upcoming missions; (2) a technology development plan to enable future mission; and (3) collaboration of possible future activities between US and international and commercial partners to maximize NASA's investments, aid in the selection of an optimal suite of missions, and enhance the exchange of scientific knowledge and data. In the absence of an Ocean Worlds Exploration Program, OPAG and the Small Bodies Assessment Group (SBAG) have jointly established an Oceans Worlds Working Group (OWWG) to develop the scientific and technological priorities for ocean world exploration with broad community participation. OPAG supports the OWWG and recognizes the importance of their activities as inputs to the Mid-Decadal Review and NASA's strategies for the second half of the decade. OPAG requests that NASA clarify how the results of OWWG's work may be most constructively relayed to the Agency.

OPAG applauds the efforts of the XAG-EDIA WG. OPAG supports NASA's ongoing efforts promoting inclusivity, equity, diversity, and accessibility of the science community. In coordination with the XAG-EDIA WG, OPAG supports the recruitment of a senior scientist as an outward-facing point of contact for improving the work culture of a broader workforce associated with SMD. Focusing on these funded externally to NASA, a coordinated effort is needed to ensure consistency across divisions to maximize existing efforts to reach NASA goals. OPAG is working with the XAG-EDIA WG on drafting the details for this potential position and invites input from NASA and community members. OPAG supports NASA's investment in training and workshops to further EDIA in NASA activities and its workforce. OPAG supports the concept of individual proposers being allowed to propose for funding to attend such workshops, as part of their proposal inclusion plans. Such federal funding can be particularly important to proposers working at institutions with limited resources and/or other restrictions for EDIA training. Future AG contracts should include funding to support DEIA training, such as bystander intervention training, for the AG SC.

OPAG was disappointed to learn that the end of the NASA support for the Lunar Planetary Institute (LPI) Publication Services threatens the University of Arizona Space Science Series books. This would adversely impact the planetary science community, both in helping to provide resources for early career researchers as well as those joining planetary science from other fields regardless of career stage. NASA's subsidization of this book series has kept them relatively inexpensive and accessible to the community for many years. Given that support for this book series is such a small cost, OPAG expresses its support for finding resources within NASA to continue this important publication line and to making the publications open access.

Nuclear fission-based power and propulsion technologies could introduce capabilities currently not available for space exploration. Fission power at the multi-kilowatt (kW) level could be highly beneficial for Ocean Worlds melt probes, while nuclear thermal propulsion could significantly reduce flight times to outer planets targets, as well as increase the deliverable mass. Based on the long technology maturation timeline and significant investments needed, with an early investment and continuing support, fission based nuclear systems could be infused into Outer Planets missions targeting the next decadal time frame. OPAG is excited about the

capabilities that could be enabled by these emerging space nuclear fission power technologies. OPAG supports efforts to leverage ongoing industry efforts on terrestrial systems, and technology developments at other government agencies.

OPAG endorses the value of international cooperation in planetary exploration. International cooperation brings benefits that outweigh any added cost and complexity in planning and executing the cooperation. International collaboration also enables further exchange of ideas to broaden participation in planetary exploration. OPAG will strive to facilitate discussions between international outer planets communities by welcoming presentations by potential international partners in future NASA outer planet missions.

Exoplanet Analysis Group

Dr. Diana Dragomir, ExoPAG Executive Committee Liaison, presented the ExoPAG update. The ExoPAG is an interdisciplinary community-driven forum which provides inputs to NASA's Exoplanet Exploration Program. They have continued monthly ExoPAG meetings, have reviewed applications for new ExoPAG members, held the ExoPAG 30 meeting in Rhode Island, are currently fostering cross-PAG communications, working on implementing community suggestions including the logo and early career engagement, and preparing the ExoPAG 31 meeting.

During ExoPAG 31, presentations from Dr. Lori Glaze, MEPAG, OPAG, Venus Exploration Analysis Group (VEXAG), XAG-EDIA WG, and the Nexus for Exoplanet System Science (NExSS) occurred. There were updates from the Science Interest Groups (SIG) 3. They had early career researcher lightning talks and interdisciplinary exchange sessions which aimed to identify current challenges in astrobiology and adjacent fields.

Small Bodies Assessment Group

Dr. Lori Feaga, SBAG SC Chair, was present to provide the update. They are currently revising the SBAG Goals Document as the SBAG priorities are guided by this document. The next SBAG community meeting will be July 11-12, 2024. There are three new SC members that were selected during June's monthly executive telecon from a large applicant pool using a rubric developed for SBAG SC positions.

Finding 1: SBAG urges NASA to take immediate action to ensure the long-term maintenance and expanded future capacity of the DSN. SBAG appreciates the PAC hearing their number one community concern and recognizing the broad reach of the issue to all planetary science missions in writing a finding and making a recommendation to NASA regarding DSN maintenance and expanded capabilities.

CAPS requested presentations from relevant AGs at the May 20, 2024 meeting on the NF Missions List Review. OWL recommended that all three of the small bodies mission concepts were unique from each other and provided distinct high-priority science for the decade. Scientific motivation has not changed since the preparation of OWL. Sample return and in situ analyses of diverse primitive populations remains a priority for the small bodies community. The community strongly supports the all-encompassing NF6 list for the next AO with respect to the small bodies mission themes.

MAPSIT

Dr. Brad Thomson, outgoing chair, was present to provide the update of the Mapping and Planetary Spatial Infrastructure Team (MAPSIT). The MAPSIT roadmap can be found [online](#). Spatial data contributes to the success of endeavors at NASA if they are correctly acquired and accessible to all interested groups. MAPSIT encourages the creation of initiatives to ensure that planetary spatial data are correctly obtained and processed and are discoverable and usable for a wide range of research and exploration purposes. As a sample finding, existing and new planetary spatial data should be easily discoverable and accessible, and data access tools must evolve with this technology.

Finding 1: MAPSIT encourages continued support for geologic mapping endeavors as a component of planetary exploration, including the Lunar Mapping Program element in ROSES 2024.

Finding 2: MAPSIT sees a community-wide need to discuss and identify critical software gaps for planetary data analysis. MAPSIT urges a SAT be formulated and requests direct involvement in this effort.

Upcoming community activities include the Planetary Geology Mappers' Meeting and Planetary Data Training Workshops.

Lunar Exploration Analysis Group

Dr. Benjamin Greenhagen, chair, presented the LEAG update. The Lunar community expresses concern over delays in landing attempts and the cadence of CLPS lander task orders, and the flow down effects to payload teams, CLPS providers, and future solicitations. Selecting CLPS providers during payload development allows for more efficient and effective engineering and avoids cost growth due to schedule extensions and storage. Maintaining a regular cadence of lander services is critical to the business models of CLPS providers and to ensure continued surface payload opportunities. The Lunar community expresses support for minimizing delays to the VIPER mission. VIPER will collect data critical to lunar science and exploration and should fly as soon as an acceptable risk posture can be achieved. LEAG requests action from the Exploration Science Strategy and Integration Office (ESSIO), CLPS, and SMD to minimize delays in all phases of robotic lunar exploration and improve communication with the community about delays and ramifications.

Significant community resources continue to drive efforts for the LEAG Lunar Science Goals activity, LEAG-ExMAG Sample SAT, and planning an International Lunar Year in 2027. LEAG thanks NASA for continuing to facilitate the Lunar Surface Science Workshop (LSSW)s, including excellent annual HQ updates, and for investigating feasibility for a similar series relevant to Mars.

Venus Exploration Analysis Group

Dr. Debra Buczkowski, Deputy Chair, presented the VEXAG update. The VEXAG has input into the NAC NF5 study, is updating the Roadmap, Tech Plan documents, and the Exploration Strategy. They have new science and analysis workgroups, the Venus Terrestrial Analogs and Venus as an Exoplanet Analog. Upcoming VEXAG events include the Venus

Sessions, Exoplanets in our Backyard 3, the 22nd VEXAG Annual meeting, the Townhall meeting, and the fourth LPI initiative meeting.

Finding 1: A “Precursor Science Investigations – Discovery” (PSI-D) R&A program, focused on ensuring success of and maximum scientific return from upcoming Discovery missions and the EnVision partnership, is in the interests of the planetary community. PSI-D could focus on any selected Discovery mission stages prior to primary Phase E science, and thus would currently specifically include VERITAS and DAVINCI, possibly EnVision, as well as Psyche and Lucy. Proposals could include laboratory studies, development, modeling, planetary mapping, precursor observations, etc. that could affect, augment, or improve late primary mission phases, and/or extended mission phases and/or enhance specific investigations or mission science goals following the model of Precursor Science Investigations for Europa (PSI-E). Proposals to PSI-D could target missions in phases B through D (or part-way through E until a mission’s primary science phase begins).

Finding 2: VEXAG finds that a solar-system-wide push for in-situ exploration technology would enable critical follow-ons to the DAVINCI, VERITAS, and EnVision missions, as well as missions to other planetary environments. The next logical step in Venus exploration is for in-situ observations (in-atmosphere, and on-surface), and we need to continue to support technology that will do this. To this end, we encourage a final HOTTech (HOTTech 3) program to focus on maturing important technologies and integration into platforms and systems, and the initiation of a new “CloudTech” program for technologies and science instruments for the Venus clouds and other planets.

Mercury Exploration Analysis Group

Dr. Carolyn Ernst, chair, presented the Mercury Exploration Analysis Group (MExAG) update. MExAG encourages NASA to work with its international partners to secure the opportunity for US participation in any future BepiColombo calls run by ESA and/or JAXA. Given that the BepiColombo nominal orbital mission is slated to begin in December 2025, support for the Guest investigator Program is time-sensitive and should not be postponed. MExAG encourages NASA to initiate a directed study of a candidate Mercury Lander flagship mission concept. This study would help to ensure a well-developed Mercury flagship mission concept is ready for the next Decadal Survey. MExAG supports protecting a healthy Discovery mission program. Discovery missions are the only avenue for NASA-led Mercury exploration in the next decade and any delays or reductions in the Discovery AO cadence will disproportionately impact opportunities for exploration of the innermost planet and the health of the Mercury community.

Upcoming Mercury and MExAG activities include planning for their next annual meeting, Mercury 2024, a Science Goal Document, recruiting new members, and BepiColombo.

Ocean Worlds Working Group

Dr. Mike Bland, co-chair, of OWWG was introduced to present the update. Their goal is to create an actionable ocean worlds exploration strategy. Their approach is utilizing previous community efforts to define prioritized science questions and identify the technology

development necessary to answer them. They have a few activities including community review of relevant literature, the organization and prioritization of key science questions, and identification of required measurements and critical technology. Actions they are taking include community Q&A sessions, working meetings of subgroups, and a joint meeting in June. Expected outcomes include a limited set of prioritized science questions that link directly to necessary technology development; a limited set of missions that address these prioritized questions, fit within NASA's existing structures, and are prioritized for additional study; and a strong, diverse, and welcoming Oceans Worlds community.

Inclusion, Diversity, Equity, & Accessibility Cross-AG Working Group

Dr. Kas Knicely, co-chair, was introduced to present the update. Upcoming activities include a speaker series and a two-day AG style meeting. He addressed two findings, one from SBAG and the other from MEPAG, that they co-sign.

They recommend the following: PAC designated one member explicitly as EDIA member and require expertise; PAC ask NASA to report on progress in collecting demographics as recommended by both the NASEM study; NASA should clarify that inclusion is not just making sure that the current team feels included but that the team should create a space where a person from any background would feel included; NASA should allow inclusion plans to include funding for EDIA training and involvement in EDIA related groups; PAC raise to the NAC recommendation that NASA establish an office of Tribal relations; and that NASA should work with NAC to create a "Senior Scientist for SMD Workforce and Culture" and the PSD should continue to advocate for this position.

PAC Discussion

Dr. Ishii led the PAC in discussion regarding the AG presentations that included the MSR samples and caches, MEPAG evaluation of studies, uniform CoC, a possible finding of OPAG support, trade studies, CLPS and VIPER delays, protecting programs, astronaut field training, and Artemis III.

Lunar Update

Dr. Sarah Noble was introduced to present the Lunar Science Strategy Update. The OWL recommended that "PSD should develop a strategic lunar program that includes human exploration as an additional option to robotic missions to achieve decadal-level science goals at the Moon." This Implementation Plan provides a snapshot of NASA's plans to implement the strategy recommended in OWL and to address the M2M objectives relevant to lunar science. It is an opportunity to present the full scope of tools currently available to NASA and how they map to high-priority lunar science that can be accomplished at the Moon. The word "integrated" in the title refers to integrating the capabilities and new opportunities afforded by Artemis and CLPS alongside more traditional mechanisms such as Discovery, New Frontiers, and various R&A elements to achieve the science objectives.

Specific missions that can be achieved through multiple architecture options: South Pole-Aitken (SPA) Basin Sample Return, Lunar Geophysical Network (LGN), and Cryogenic Volatile Sample Return. Objectives that require a build up of knowledge and global access to samples to

achieve include Lunar Chronology and Lunar Formation/Evolution. They released the Draft back in November and received multiple responses. They appreciate the feedback. While they will not provide a bullet-by-bullet response, they did read and consider each and every comment and have made substantial changes in response. The final version is expected this month or next.

Major changes since the Draft release include: clarification that the document is focused on the science that they can extract from the current and evolving lunar architecture, and does not discuss the important role that science plays in enabling exploration; volatiles added as a sixth “big challenge”; Lunar Exploration and Science Orbiter (LEXSO) section was clarified and reworded to focus on science objectives rather than the strawman payload; there was clarification on Artemis SDTs and strategic input; and the addition of new ROSES elements to the Lunar Mapping Program (LMap).

She discussed upcoming activities that they are committing to undertake over the next two years and the forward work for the next iteration.

Lunar Discovery and Exploration Program Update

Dr. Joel Kearns, Deputy AA for Exploration Science Mission Directorate, was introduced to present the LDEP update. He provided graphics of the Chang’e-6 landing site in the Apollo Basin on the far side of the Moon, the Lunar Reconnaissance Orbiter (LRO), the VIPER flight rover, the Lunar Trailblazer, and the Far Side Seismic (FSS) Suite. NASA announced the Artemis III Deployed Instruments (A3D1) competitions along with upcoming competitions including PRISM Stand Alone Site Agnostic (SALSA). He discussed the CLPS task order for Prime1 and CLPS task order 19D. He discussed the fleet chart of lunar missions.

Lunar Reference Frame Update

Dr. Robin Ferguson was introduced. She brought up the PAC finding from November 2023, as reference for this briefing: The PAC recognizes NASA’s potential influence over planetary mapping standards and that the relevant planetary science communities have weighed in on the question of lunar reference frames. The PAC endorses the MAPSIT/LEAG white paper, including their reasoning and findings.

A reference coordinate system is an overall concept, including theory and conventions to form an idealized coordinate model. A reference coordinate frame is a specific realization of the system. Two common lunar reference systems that exist include the Mean Earth/polar axis (ME), or Mean Earth/Rotation (MER), and Principal axis (PA) or axis of figure. The differences between these systems vary, usually by several 100 meters. This is due to asymmetry in the lunar gravity field. This is obviously significant for most purposes. She discussed the current PA and ME frames and why the reference frame matters.

The PSD Funds the development, maintenance, and publishing of celestial body ephemerides and reference frames for all bodies in our solar system. A PA system-based frame has been proposed for all lunar use, including surface navigation and mapping. There are concerns regarding the continued use of a ME system-based frame especially the need to use both frames while doing cislunar navigation, causing potential confusion or error. The authors of

LEAG WP have considered various possible issues and believe an ME frame should continue to be used for mapping and PA frames can continue to be used for dynamical purposes. Both the LEAG and the Planetary Science Advisory Committee have endorsed the paper's conclusions.

LEAG Finding 1: The difference in the ME and PA coordinates of a point on the lunar surface is at least several hundred meters. Lunar surface operations could be considerably affected if the coordinate system is misunderstood.

LEAG Finding 2: An ME frame is as accurate as the corresponding PA frame, but ME frames are held fixed with respect to surface features. The ME frame is most appropriate for use in lunar mapping.

LEAG Finding 3: the resources that would be required by the international lunar science and engineering community to change the large volume of existing lunar data and information from the current ME to the PA system would be substantial.

LEAG Finding 4: the confusion introduced in use of many existing datasets, data products, databases, and publications by changing from the ME coordinate system to the PA system would be substantial.

The lunar science and exploration community needs to be aware of these two systems and frames and their uses. If a PA system-based frame begins to be used for mapping and navigation, all users will have to take much more care about which system data and products are in. The NASA Federated Board has created a working group to make recommendations regarding the use of lunar reference frames. No matter the outcome, better international cooperation on lunar standards for mapping and navigation would be useful. Perhaps with an expansion to an international Lunar Spatial Data Infrastructure or as a possible *International Lunar Year* project.

The Lunar Reference Frame Working Group identified the following work items: M2M architecture and infrastructure discussions are underway; ensuring that all stakeholders are included in relevant NASA discussions; ensuring that NASA stakeholders needs, requirements, and justifications are clearly and accurately documented; and determining the needed immediate and longer-term actions. Dr. Ferguson discussed the working group approach and representation within the working group.

The goal is to develop an internal NASA consensus on recommended lunar reference systems and frames for specific use cases as multiple use cases and architectural elements are emerging that require definition of a lunar reference system. There are some solution constraints. She discussed future efforts as they relate to this update.

Dr. Woods asked how accurate the conversions are between the frames and what tools exist? This is matrix algebra. This is not the largest source of error and really is just math. There are tools but they are not readily available to the general public.

Dr. Jessup stated that there needs to be communication about preference. From a technical perspective, this is a soft problem – it is just about communication. This is not a technical problem, it's a communication problem.

There was discussion about a potential finding endorsing the new release during the November meeting.

Public Comment Period

Dr. Ishii opened the public comment period.

A. Hendrix commented that while they are having some MOSSFET issues with the Europa Clipper, they are hoping to have the support of the PAC for the upcoming flagship mission.

S. Diniega commented that based on her experience, a CoC can be insufficient, and the main gap is enforcement. LPI's reach is limited, at least defined by their lawyers, as well as their visibility into the events. It would be better for NASA to create a template to be used. Dr. Braccio stated that she would have to check the accuracy of that statement. Having resources for sending members for assistance with issues could be very helpful.

PAC Discussion

Dr. Ishii led the PAC in discussion regarding multiple topics including volatiles return, ESSIO process, review of VIPER, the budget and cost caps, VERITAS, SIMPLEx, Lunar and Mars missions collaboration, CLPS, pipeline programs, inclusion plan training, DSN, ANSMET, and Artemis instrument calls.

July 11, 2024

PSD R&A Update

Dr. Kathleen Vander Kaaden, Acting Director of Planetary Research, and Dr. Delia Santiago-Materese, Acting Deputy Director of Planetary Research were introduced. Staff updates were highlighted. She discussed the Planetary R&A Research budget.

Astromaterial samples in proposals were addressed. Prior to funding being sent on an award that requires the acquisition of Astromaterials, proposers must demonstrate that the samples will be allocated to them. The samples do not need to be in-hand prior to the release of funds. The proposers must only demonstrate that they will receive the samples. Requests to access NASA's Astromaterials are made to the Astromaterials Allocation Review Board (AARB). Different collections have different deadlines, and some have no deadlines. Funding for proposals that require Astromaterials has been handled differently and inconsistently in the past. This is an effort to standardize the practices, set expectations with the community, and better manage the program funds. Fieldwork in ROSES 24 has new requirements. First year of new requirements, more leniency provided, phased planning.

She highlighted recent IDEA activities in PSD R&A including partnership building, internal efforts, and TWSC support. Mentorship and opportunities in Science, Technology, Engineering, and Math (STEM) with academic institutions for community success was discussed along with research initiation awards. She touched on the types of these awards, specifically no cost extensions (NCE).

Dr. Vander Kaaden touched on the No Due Date (NoDD) Programs Review Plan. They were not the originators of this idea, and they are not the only ones doing it. There are a lot of lessons learned that can support the improvement of NoDD as there are a lot of common motivators across agencies. She discussed the history of NoDD in PSD R&A. She reviewed the core principles, initial established metrics, additional revised metrics, and additional questions to address. SMD PSD R&A does not have an allowable mechanism to solicit community feedback at this time. If the PAC feels that community feedback is warranted, PAC members could explicitly ask the community to send feedback via email about NoDD. PAC members could then consolidate that response and discuss them in an open session. If such feedback is solicited, it would be important to make sure that the responses are representative of the community. This is not a formal request from SMD PSD R&A to solicit this feedback.

She discussed the continuation of reducing barriers to proposing. At the start of the COVID pandemic, proposers communicated with various PSD staff members about decreased life flexibility considering various challenges, including increased caretaking responsibilities and change in work patterns. Others shared experiences of challenges submitting proposals from small institutions when one staff person was out, or if a natural disaster hit. NoDD programs in PSD R&A were started in response to these reported challenges to allow flexibility in submission

due dates, which are strictly enforced. SMD is looking at ways to reduce barriers. She highlighted recent actions they've taken to reduce barriers to proposing.

Astrobiology Update

Dr. David Grinspoon, Senior Scientist for Astrobiology Strategy, and Dr. Becky McCauley Rench, Deputy Program Scientist for Astrobiology, were introduced. The astrobiology research programs discussed included Exobiology, Habitable Worlds (HW), Planetary Science and Technology Through Analog Research (PSTAR), and Interdisciplinary Consortia for Astrobiology Research (ICAR). ICAR is solicited in ROSES 24 and an updated text will be released soon. Proposals with a primary relevance to NExSS are not being solicited this year. Both phases of the Search for Life at Mars were discussed along with Astrobiology Strategy 2025. The NASA-DARES 2025: The 2025 NASA Astrobiology STRATegy for Decadal Advancements in Research, Exploration, and Synthesis by Dr. Rachel Harris was highlighted.

Dr. Grinspoon spoke on the astrobiology as the study of life's origin, evolution, distribution, and future. He discussed the Astrobiology and the Future of Life workshop and a Metagenomics workshop. He touched on the Established Program to Stimulate Competitive Research (EPSCoR) FY25 Rapid Response Research (R3) Solicitation.

RCN Updates

NOW: Network for Ocean Worlds

Dr. Chirs German was introduced to provide the update on NOW, the Geo- and Life-Science Research on Earth Space-Science Expertise. He touched on the network community and how they have 75 NASA funded projects with over 250 plus active researchers. The research themes and link associated with Ocean Worlds include physical properties, life detection, analog studies relevant, and new technologies. He discussed the 2023-2032 Decadal Plan and how it was the first to incorporate Planetary Sciences and Astrobiology with an explicit recommendation to NASA to develop a strategy for Ocean Worlds Exploration. NOW has joint action with OPAG to create a strategic Ocean Worlds WG. He discussed the effective engagement community wide.

NExSS

Dr. Ofer Cohen was introduced to present for NExSS. Their goals, achieved by interdisciplinarity, include studying planetary habitability and the search for life on exoplanets; answering fundamental questions related to planet formation, evolution, diversity, habitability, and signs of life; and membership is open to any scientists working in NExSS science areas. NExSS science goals include understanding planets in context throughout their formation and coevolution with their parent star and planetary system; investigating the diversity of exoplanet characteristics and learn how their properties and evolution can create the conditions for life; understanding how to identify the best exoplanet targets for life searches; and learning how to recognize, and search for, signs of habitability and life on exoplanets. NExSS builds community and advances science with interdisciplinary, inter-RCN workshops and conferences; collaborative exoplanet observing communities; science working groups; and quarterly steering

committee meetings, slack workspace working groups, and more. NExSS membership was discussed.

Public Comment Period

Dr. Ishii opened the public comment period. No comments were received.

Chris German commented that as a member of the public, he was interested to see how PSD R&A monitored balance in the portfolio and wonder whether there has been any thought to combining how PSD R&A portfolios are evaluated to gain insights from one another.

Discussion

Dr. Ishii started the discussion over the PAC's findings that have been in development since the beginning of the meeting. Conversation occurred over multiple topics including R&A, the Decadal Survey, NoDD proposals, and lessons learned.

Adjournment

Dr. Ishii thanked all PAC members for their dedication and hard work and all major and support staff that supported the PAC meeting. The next PAC meeting date was discussed for November. The meeting was then adjourned.

Appendix A Attendees

PAC Members

Hope Ishii
Shannon Curry
Lisa Danielson
John Grant
Deborah Woods
Brent Barbee

Kandi Jessup
Morgan Cable
Tyler Robinson
David Murrow
Louise Prockter

Attendees¹

Aaron Burton
Adrian Brown
Alana Johnson
Alison Murray
Amanda Hendrix
Amy Reis
Anna Maria Pal
Anne Verbiscer
Anthony Colaprete
Ashley Mae
Barbara Cohen
Becky McCauley Rench
Ben Greenhagen
Bobby
Bobby Fogel
Brad Thomson
Brent Archinal
Brett Denevi
Btrieu
Caleb Fassett
Caleb Scharf
Caroly Ernst
Casey Dreier
Chris German
Christina Viviano
Christy Layton
Curt Niebur
Curtis
Curtis Williams
Cynthia Evans
Dan Opstal
Daniel Andres
David Eisenman
David Grinspoon
David J. Smith
Deb Hernandez
Debra Buczkowski
Debra Needham

Delia Santiago-Materese
Dwayne Washington
Diana Dragomir
Douglas Hudgins
Elaine Denning
Elena Steponaitis
Erica M
Erin Morton
Erwan Mazarico
George Tahu
Gina DiBraccio
Greg Ruda
Hannah Jang-Condell
Henry Throop
J.L. Galache
Jack Kiraly
James Lochner
James T. Keane
Jefferey Hollingsworth
Jeffrey Gramlin
Jemma Davidson
Jennifer Kearns
Jessica Noviello
JM
Joel Kearns
John Brown
John Rummel
Jordan Garberding
Jorge Nunez
Jose Hurtado
Juliana Gross
Julie Grantier
Julie Rathbun
Julie Stopar
K. Estelle Dodson
Kanisha Armintia
Kathleen Vander Kaaden
Kathryn Pietro

¹ The names and/or affiliations are as given by the attendees, and/or as recorded by the teleconference operator.

Katie Robinson
Kelsie Krafton
Kimberly Ennico-Smith
Knicely
Kristen John
LaJuan Moore
Lauren Jozwiak
Laurie Barge
Leo Enright
Leopoldo Gomez
Leviticus Lewis
Linda Billings
Lori Feaga
Luke Sollitt
Maitrayee
Mallory Kinczyk
Mariah Baker
Mark McClerman
Mary Voytek
Matthew Miller
Maz Bernstein
Meagan Thompson
Melissa Kirven
Melissa Morris
Melissa Pamer
Michael Kalin
Michael Lienhard
Michele Gates
Mike Bland
Mitchell Schulte
Monica Washington
Morgan Cable
Nalin Ratnayake
Nick Lang
Nilufar Ramji
Nina Lanza
Ofer Cohen

Patrick Taylor
Paul Byrne
Paul Voosen
Philipp Heck
Rachel Harris
Ramon De Paula
Richard Rogers
Richard Zurek
Rishika
Robin Fergason
Ryan Watkins
Samantha Jacob
Sandra Connelly
Sarah Noble
Sarah Valencia
Serina Diniega
Shannon Fitzpatrick
Stacy Cook
Stephen Watson
Tahira Allen
Tait Francis
Tammy D
Tammy Dickinson
Tiffany Morgan
Tom S
Tom Statler
Tommi Koshinen
Trent
Tylor Cingle
William Knopf
Yang Liu
Zhengwei Hu
Zoe Wai

Appendix B

Planetary Science Advisory Committee Members

Dr. Hope Ishii, Chair
University of Hawaii at Manoa

Dr. Shannon Curry, Deputy Chair
University of California, Berkeley

Dr. Katie Robinson
NASA Executive Secretary

Dr. Walter Kiefer
Lunar and Planetary Institute

Dr. Lisa Danielson
Los Alamos National Laboratory

Dr. D'Arcy Meyer-Dombard
University of Illinois at Chicago

Dr. Tyler Robinson
Northern Arizona University

Mr. Brent Barbee
NASA Goddard Space Flight Center

Dr. Kandi Jessup
Southwest Research Institute

Dr. John Grant
Smithsonian

Dr. Louise Prockter
Johns Hopkins University Applied Physics Laboratory

Mr. David Murrow
Retired (Lockheed)

Dr. Morgan Cable
Jet Propulsion Laboratory

Dr. Deborah Woods
Massachusetts Institute of Technology Lincoln Labs

Appendix C Presentations

1. Mars Sample Return, *S. Connelly, P. Hertz*
2. NASA Science Planetary Science Advisory Committee (PAC), *G. DiBraccio, S. Fitzpatrick*
3. IDEA AG, *J. Rathbun*
4. Mars Exploration Program, *E. Ianson, M. Schulte*
5. DSN Update, *P. Baldwin*
6. NASA's Moon to Mars Architecture, *J. Bleacher and J. Grantier*
7. ARTEMIS: Artemis Geology and Lunar Science Training Overview, *C. Evans*
8. Sample Questions from the PAC, *B. Cohen*
9. MEPAG Update, *V. Hamilton*
10. ExMAG, *P. Heck*
11. OPAG, *A. Hendrix*
12. ExoPAG, *D. Dragomir*
13. SBAG, *L. Feaga*
14. MAPSIT, *B. Thompson*
15. LEAG, *B. Greenhagen*
16. VEXAG, *D. Buczkowski*
17. OWWG, *M. Bland*
18. Lunar Science Strategy Update, *S. Noble*
19. Lunar Discovery and Exploration Program, *J. Kearns*
20. Lunar Reference Frame Update, *R. Fergason*
21. Planetary Science Division R&A Update, *K. Vander Kaaden*
22. NASA Astrobiology Program Update, *D. Grinspoon*
23. NOW: Network for Ocean Worlds, *C. German*
24. NASA's Nexus for Exoplanet System Science: Working Together to Find Life in the Universe, *O. Cohen*

Appendix D
Agenda

Planetary Science Advisory Committee Meeting
Hybrid
July 9-11, 2024

<u>Tuesday, July 9</u>		
1000 AM	Welcome & Introductions	Katie Robinson, Hope Ishii
1015 AM	MSR IRB Response Team (MIRT)	Paul Hertz
1145 AM	PAC Q&A/Discussion	PAC Members
1215 PM	Lunch	
0115 PM	PSD update	
0215 PM	IDEA Cross-AG Working Group	Gina DiBraccio, Shannon Fitzpatrick
0245 PM	PAC Q&A/Discussion	Julie Rathbun, Kas Knicely
0300 PM	Break	PAC Members
0330 PM	Mars Exploration Program	Eric Ianson, Tiffany Morgan
0430 PM	DSN Usage Update	Philip Baldwin
0500 PM	Public Comment Period	
0515 PM	PAC Q&A/Discussion	PAC Members
0600 PM	Adjourn	

Agenda

Planetary Science Advisory Committee Meeting

Hybrid

July 9-11, 2024

Wednesday, July 10

1000 AM	Moon to Mars Architecture	Julie Grantier, Jacob Bleacher
1100 AM	Artemis Science Planning	Cindy Evans, Barbara Cohen, Juliane Gross
1130 AM	PAC Q&A/Discussion	PAC Members
1200 PM	Lunch	
0100 PM	Assessment/Analysis Group (AG) Updates	AG Representatives
0300 PM	Break	
0330 PM	ESSIO/Lunar Update	Joel Kearns, Sarah Noble
0400 PM	Lunar Reference Frame Update	Robin Ferguson
0430 PM	Public Comment Period	
0500 PM	PAC Q&A/Discussion	PAC Members
0600 PM	Adjourn	

Agenda

Planetary Science Advisory Committee Meeting Hybrid July 9-11, 2024

Thursday, July 11

1000 AM PSD R&A Update
1100 AM PAC Q&A/Discussion
1130 AM Astrobiology Update
1200 PM RCN Updates
1220 PM Public Comment Period
1230 PM PAC Q&A/Discussion
0130 PM Adjourn

Kathleen Vander Kaaden, Delia Santiago-Materese
PAC Members
David Grinspoon, Becky McCauley Rench
Chris German, Ofer Cohen
PAC Members