

NASA ADVISORY COUNCIL  
PLANETARY SCIENCE ADVISORY COMMITTEE

March 9-10, 2020

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Washington, DC

MEETING REPORT

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Anne Verbiscer, Chair

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Stephen Rinehart, Executive Secretary

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### Opening, Announcements, Around the Table Identification

Executive Secretary of the Planetary Science Advisory Committee (PAC), Dr. Stephen Rinehart, opened the meeting and made administrative announcements. PAC Chair, Dr. Anne Verbiscer, welcomed everyone to the virtual meeting. Announcements were made around the table and on Webex.

### PSD Status Report

Dr. Lori Glaze, Director of the Planetary Science Division, gave a status report. First addressing the President's Budget Request (PBR) for Fiscal Year 2021 (FY21) for the Science Mission Directorate (SMD), Dr. Glaze noted that it was one of the strongest science budgets in NASA history, representing a 12% increase over the enacted FY20 budget. The total PBR keeps NASA on track to land on the Moon by 2024; and to help prepare for human exploration at Mars. The proposed budget supports initial planning for Mars Sample Return (MSR) and the Europa Clipper mission. NASA's budget strategy includes support for Artemis with enhanced lunar science and technology demonstrations, strengthening the link between SMD and the Human Exploration and Operations Mission Directorate (HEOMD); enables development of more than 15 missions; bolsters crucial science with the Commercial Lunar Payload Services (CLPS) initiative, which will see its first two launches in 2021; the search for lunar polar ice in late 2022/early 2023; a lunar rover mission that builds on earlier lunar investments, the Volatiles Investigating Polar Exploration Rover (VIPER); and science studies for developing a Mars Ice Mapper (MIM).

The budget will also advance the development of a Near-Earth Object Surveillance Mission (NEOSM), an infrared survey telescope that will search for and monitor NEOs, as well as advance international and commercial partnerships.

The top line FY21 budget for Planetary is \$2.659B, about \$53M less than had been appropriated for FY20; here it is important to emphasize the substantial increase for Research and Analysis (R&A), which is a high priority for PSD, and support for some Decadal Survey missions.

In terms of proposed budgets and enactments, Congress has typically appropriated increases over the proposed budget at the SMD level, dating back to 2013. A number of changes with FY21 include support for the launch of the Clipper on the Space Launch System (SLS) as currently required by law; the budget also proposes, alternatively, a Clipper launch on a commercial launch vehicle at a savings to the mission of \$1.5B. Dragonfly, a mission to the saturnian moon, Titan, has been selected as the newest New Frontiers mission, scheduled to launch in 2026. The budget also increases CLPS and future opportunities in the Small Innovative Missions for Planetary Exploration (SIMPLEx) program; increases R&A to maintain adherence to Decadal Survey recommendations; and begins MIM planning with international and commercial partners.

What is the same in the budget: it enables an MSR launch in 2026; implements the Mars 2020 rover, (M2020: Perseverance); the Double Asteroid Redirection Test (DART), Dragonfly, asteroid missions Psyche and Lucy, and U.S. instrumentation on the European missions Exomars 2020, JUICE, and MMX. The budget also supports step 2 selections in the Discovery program; and a New Frontiers Announcement of Opportunity (AO) release in late Calendar Year (CY 2022). There is no funding for a Europa Lander, but the budget maintains radioisotope power capabilities.

Appropriations for FY20 maintained a trend in substantial increases over the past 5-6 years for SMD, which is now holding steady at a strong level. An Operating Plan has been submitted to the Hill. More details will be available as the Plan goes through the approval process. Dr. Glaze note however that the funding came in with specific Congressional interests, leaving about \$67.8M less for the "Other PSD" category (which includes R&A). The PSD fleet stands at 25 missions, with 13 in operations and 12 in formulation and implementation, the latter with launch dates between now and 2026. PSD budget lines

will now show CLPS and VIPER. VIPER has recently been transitioned to PSD, and will be managed through the division henceforth.

Three SIMPLEx missions are moving to phase B, with Preliminary Design Reviews (PDRs) scheduled in the Summer and Fall. Four Discovery phase A studies are under way: the Io Volcano Observatory, which is focused on following the heat in the icy moons around giant planets; the mission is a Jupiter orbiter that would carry out ten fly-bys of Io. The second is the TRIDENT mission to Neptune's moon, Triton, one of the Solar System's most unusual moons, thought to be a captured Kuiper Belt Object (KBO). Triton has a young surface, which may have liquid water beneath its icy crust. Third is DAVINCI-plus, a mission to Venus, an entry probe that would take *in-situ* measurements on a descent to the planet's surface, with an orbital component (-plus) that would perform infrared (IR) mapping through the clouds. Fourth, VERITAS, another mission to Venus, would be an orbiter that carries an IR spectrometer to do surface mapping, and other characterization. It is an exciting mission set; no matter which mission is selected, it will expand the science reach of PSD.

Discovery cost growth, resulting from strategic decisions, led to a selection of four instead of five missions. PSD is looking very closely at what the budget can sustain. Dr. Glaze described herself as a staunch supporter of the Discovery program; however, the costs of these missions have grown over the last 20 years, making it challenging to launch with the desired frequency. Dr. Glaze emphasized that she wished to leave open the possibility of selecting a fifth mission, especially in the light of meeting Decadal Survey recommendations. Some of the reasons behind the changes that have driven the cost growth of Discovery, include changes in program accounting, such as the removal of the launch vehicle (LV) and phase E funds from the cost cap given by the AO. Entire life cycle costs for Discovery missions were intended to be under \$500M, in order to support two launches per decade. This is no longer the case; the Lucy and Psyche missions, for instance, are each at around \$1B. Costs must be kept in mind as PSD moves forward to balance cadences in the Discovery program.

PSD is planning for the 2023 Planetary Decadal Survey (DS). The statement of task is complete and ready for submission; a white paper website and chair announcements will be coming soon. The month of May is the rough deadline for white paper <sup>1</sup>submissions. The white paper submission process will be similar to previous one, and the vetting will be led by the National Academies of Sciences (NAS) Space Studies Board (SSB). The Lunar and Planetary Institute (LPI) website for community white paper collaboration is open. The 16-20 March Lunar and Planetary Science Conference (LPSC) has been cancelled due to the coronavirus situation. NASA is working to identify times for holding virtual Early Career workshops and an LPSC Town Hall for the Decadal Survey (DS). The Planetary Mission Concept Studies (PMCS) meeting is considering postponement for a month or so, as it is thought waiting for a face-to-face meeting would be beneficial, if possible.

Dr. Glaze detailed a conflict of interest statement with regard to DS participation as follows:

*Prospective members of all National Academies' committees and panels have their financial relationships reviewed to prevent actual or perceived conflicts of interest. Additionally, the National Academies evaluates whether each prospective member is a strong, publicly known advocate for a specific project—broadly defined as a plan, mission, initiative, architecture, or the equivalent—that the committee or panel may evaluate. Such evaluation is necessary to avoid possible bias or a perception thereof. Nominations and self-nominations to the decadal survey committee—i.e., the steering group and supporting panels—are welcome.*

*Nominees with the following characteristics are encouraged:*

- *Scientific and technical expertise, and objectivity;*
- *Experience in the management of a project, organization, or equivalent enterprise is desirable;*

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<sup>1</sup> Although this is an accurate reflection of what was discussed, should we add a footnote that the deadline has since slipped to July 4<sup>th</sup>.

- *Must be broad thinkers, open-minded, and not active proponents of a specific project; and*
- *Be able to participate in-person in survey committee activities.*

*Additional considerations include the following:*

- *All authors of science-focused whitepapers prepared for the survey are eligible to be considered as members of the steering group and its supporting panels;*
- *First authors of mission-focused whitepapers prepared for the survey cannot serve on the steering group or on any panel considering that mission; and*
- *Principal investigators of the NASA-funded, pre-decadal mission-concept studies to be evaluated by the survey cannot serve on the steering committee or on any panel considering that mission.*

Dr. Glaze reported that the first “PI Launchpad” meeting had been a roaring success, and regarded as an impactful training opportunity for researchers who wish to lead future NASA missions. Almost half of the participants were from the planetary disciplines. SMD is planning to hold another Launchpad in late Summer 2020, possibly at the University of Michigan. As to the discipline Analysis Groups (AGs), PSD continues to work within the new reporting structure, and is in the process of writing new Terms of Reference (TORs). There seems to be a good path forward; the target date to resolve the AG situation is June 2020. PSD is also trying to provide more consistent and transparent funding support for the AGs, and provide more clarity for feedback avenues.

Responding to findings from the PAC’s previous meeting, Dr. Glaze reported that PSD has moved forward on the Committee’s recommendation on instituting Dual Anonymous Peer Review (DAPR) for reviewing proposals. In creating the DAPR process, PSD was aided greatly by consulting on best practices with two social scientists at the Space Telescope Science Institute (STScI), which employs similar reviews. SMD has performed its own studies and has found no evidence for gender bias, but no results exist for institutional bias. SMD is strongly committed to ensuring that proposal review is performed in a fair and equitable way; DAPR is helping to limit discussion of “the team”, and is shifting focus more to scientific merit. Responding to a finding on commercial satellite constellations and their potential (visual) impact on NASA’s ground-based observations, Dr. Glaze reported that all of SMD is currently working to identify the appropriate approach to assessing the impact. Responding to a finding on the major equipment/facilities (PMEF) 2018 selection delay and cancellation of a call for 2019, PSD intends to make selections from the PMEF-18 call, and will be standing up a new facilities call as part of ROSES20, at a higher budget level.

Dr. Amy Mainzer commented that the proposed NEO survey telescope appears to be not fully funded for launch. Dr. Glaze said to keep in mind that the FY21 budget is still under discussion. NASA will continue to move forward with the surveillance mission, and is hoping to move to phase B soon. Funds in the relevant budget line will start to increase as DART rolls off; if NASA gets additional funding, NEOSM can launch sooner. Dr. Chris German asked re: Europa Clipper— what are the launch date impacts on arrival time at Europa? Dr. Glaze said she did not have the answer off-hand, but would seek them and provide them to the PAC. Asked about potential for a Europa Lander, Dr. Glaze felt there was nothing to preclude its consideration in the next Planetary Decadal Survey. Dr. Verbiscer asked if there might be a delay in when the DS studies are due. Dr. Glaze felt any delay might actually be beneficial for PMCS preparation, but didn’t think it would delay due dates for reports. Dr. Stroud commented, in regard to Discovery selections, that there was a lot of specificity about programmatic decisions in the letter; she asked if it would be possible to get this information before the calls. Dr. Glaze surmised that she had been referring to decisions about lunar and small body selections, and noted there were many missions that did extremely well in the Discovery process. All category 1 and 2 missions were considered and were on the table for the selecting official, Dr. Thomas Zurbuchen, but Dr. Glaze noted that there had been no upfront decisions about eliminating certain targets. She appreciated the concern, however.

### PSD R&A Status

Dr. Rinehart gave a presentation on Planetary Research, and the status of the ROSES19 call. Selections for ROSES19 are currently being made, and there will be much more information available by the time of the LPSC Town Hall. A full list of appendices is online for ROSES20. Some changes are the inclusion of a Yearly Opportunity for Research in Planetary Defense (YORPD); a Participating Scientist Program (PSP) for the Mars Organic Molecule Analyzer (MOMA: now canceled for ROSES20 due to a delay in the launch of ExoMars) and for DART; support for open source tools, frameworks and libraries, and support for supplemental open source software awards.

PSD is working on trying to get a better picture of the R&A budget over the last few years, and is performing an overview of research program budgets; the budget has grown by about 10% over the last four years. Results are expected soon. In response to a National Academies of Sciences, Engineering, and Medicine (NASEM) report on a Sample Receiving Facility (SRF), PSD found the report contained good recommendations, but it was lacking in regard for NASA's budgetary constraints. Nonetheless, it is important to address the NASEM findings, and PSD is now exploring ways to provide support for PSD-relevant facilities, by enabling development and upgrades of valuable facilities, ensuring support for the community, and providing effective oversight. The plan is to have two calls that would replace current PMEF calls on planetary major equipment. The calls would look much like the current PMEF program, but would be one- to two-year efforts. Every two years, PSD proposes to make \$5M available for year 1 of new awards. Budget and planning are going forward for conducting facilities calls every two years, with reviews every two years (halfway between each call). Dr. Rinehart anticipated that this program would ramp up to \$10M per year relatively quickly, perhaps growing as large as \$15M per year.

Research on lunar samples has a history of being a gray area, with overlap between Emerging Worlds (EW) and Solar System Workings (SSW); thus PSD is concerned about the negative effect this ambiguity might engender in splitting up projects or contorting research. Proposals in SSW have been sent to EW to take advantage of reviewer expertise. SSW19 received a large number of proposals, ensuring sufficient depth of reviewer expertise for current review. The solution for the present time is that PSD will abandon idea of sending all lunar sample proposals to EW.

Addressing gaps in requests for information (RFIs), NASA SMD is soliciting information on research that is aligned with the agency mission and with SMD's Science Plan, but falls in a gap between current solicitations, possibly because it is interdisciplinary or interdivisional. SMD received 104 responses, 40 of which are of interest to PSD, and SMD is now in the process of categorizing all of the responses. PSD will present a thorough analysis and some public findings and recommendations within a few months.

There was a Town Hall (TH) meeting on the subject of DAPR during the first week of March, led by Dr. Michael New, which was extremely well attended via Webex (300 participants). PSD expects to have more THs, especially as the Habitable Worlds call draws near; this will be the last of the four DAPR test cases. The real point of the exercise has been to focus reviewers on judging the intrinsic science merit of proposals. Feedback from the Space Telescope Science Institute (STScI) has thus far been very positive. Participating reviewers have noted that discussions have been more collegial, as well.

Dr. Mainzer said it was heartening to see the expansion of sample return funding coming along. Dr. Rinehart stressed that it's a work in progress but that PSD is committed to this course. Asked if there had been any impact to the Mars program budget from this facilities issue, Dr. Rinehart said there had been no impact yet, nor any cost-sharing required (but which might be encouraged). Asked about funding for NASA facilities, Dr. Rinehart reiterated that PSD intended to do a review, then fold in all facilities into the portfolio, which will then all be treated the same. While the budget for this effort has not been determined, the intent is that the \$5M/year allocation would be on top of what NASA currently spends on facilities, i.e. new money. A meeting attendee commented that the R&A budget seems significantly

higher: will it be spread out or is there a specific program intent for this budget? Dr. Glaze said that some part of the budget is intended to cover the Decadal Survey, but not for any particular line. However, it should be noted that not all of the R&A funding is for competed R&A. PSD is looking for a consistent way to show the “real” R&A budget (Meagan Thompson is working on this).

#### Working Lunch (Annual Ethics Training for the PAC)

Committee members received their annual ethics training.

#### Planetary Protection

Dr. Rebecca McCauley Rench presented a status of Planetary Protection (PP) at NASA. ROSES last had a PP call out in 2018, which was a late edition due to government shutdown. NASA made selections in November 2019, maintaining a 20% selection rate. Projects selected included studying deep ultraviolet fluorescence and Raman mapping. There will not be another call until ROSES 21, after which a regular cadence is planned. The Office of Planetary Protection (OPP) is currently updating the NASA Procedural Requirements (NPR) document for human and robotic missions, which will be finalized by the end of this calendar year. OPP is also coordinating with Human Exploration and Operations (HEO) and the Space Technology Mission Directorate (STMD), and is setting up a cross directorate steering committee.

Recently, NASA received the results of the Planetary Protection Independent Review Board (PPIRB), chartered in July 2019 and chaired by Dr. Alan Stern. The IRB included a large cross-section of expertise across academia and industry. The PPIRB’s 77 findings and recommendations were briefed to NASA and the NASA Advisory Council (NAC) in October 2019. NASA is responding to the report by developing new policies, and initiating new studies, where necessary, with the National Academies. NASA has requested a new committee on PP from the Space Studies Board (SSB), to provide an independent and authoritative forum for the airing of issues in all areas of PP. The first agenda item for this committee is a proposed a study on lunar planetary protection in terms of protecting areas of the Moon’s surface and subsurface from contamination. The study will focus on areas such as protection of historical sites and permanently shadowed regions (PSRs), and seeks to provide a coherent and consistent traceability of recommended research to minimize the threat of contamination. OPP is also working on a NASA Interim Directive (NID) on robotic and crewed missions to the Moon, currently going through the approval process. Under this NID, the PP categorization of robotic missions to the Moon would be Category 1 (unrestricted access), with the exception of the Apollo landing sites and PSRs. In addition, there is an upcoming Committee on Space Research (COSPAR) meeting, which is also working on setting science requirements for Mars Sample Return (MSR), as well as a communications plan that will be ready in April.

In answer to a question on the SSB PP committee, Dr. Rench said it the new committee will be mixture of stakeholders from academia, industry, and stakeholders across the board, chosen by SSB. Asked whether it would be permissible to ship tardigrades to the Moon, Dr. Lisa Pratt, Planetary Protection Officer noted that when and how to protect science research at the Moon will also be considered by the European Space Agency (ESA) and the Japanese Space Agency (JAXA). Dr. Pratt said she was not in favor of tardigrade contamination on the Moon, but that there are currently no (international or domestic) prohibitions against shipping organic/biological materials to the Moon. Going forward, the NASA NID will reduce some reporting and documentation burden in lunar areas. In the mid- and lower latitudes of the Moon, no reporting is needed for Category 1 missions. NASA is assuming sufficient odds of (a lander) not crashing into PSRs. The tardigrade situation, as well as other biologicals, could easily recur. NASA has submitted a formal request to stand up the PP Committee, and expects it to be a quick turnaround, absolutely before Fall 2020.

Dr. Rinehart opened the line to the public for this topic. Dr. Louise Prockter, from Lunar and Planetary Institute (LPI) commented that a PP traceability matrix should be useful, and asked if it would be ready

for consideration by the next Planetary Decadal Survey. Dr. Glaze said she could ask that the study remain in synchrony with some DS issues, which will be off and running this summer. Asked if the new PP committee planned to include the assessment of commercial access to PSRs and potential contamination, Dr. Pratt commented that the PPIRB was very well represented by the commercial sector; she said that a commercial actor who wants to explore PSRs would have to meet Category 2 requirements, governed by COSPAR guidelines, at present. The intent is not to block out commercial and other actors, however they will need to reveal what they will be delivering to the Moon if they are actively excavating and drilling. As to crewed missions to PSRs, Dr. Pratt said while the PP NID in progress is NASA's internal document, it will be reviewed by the NAS. She expected that crewed missions will be asked to describe any potential waste they would leave behind. There are no prohibitions for Category 1 missions, but all missions will be asked for transparency. NASA is trying to protect the science until there is more information about how materials are altered at the Moon over time.

#### PAC discussion – feedback on morning's topics

Dr. Mainzer addressed the Mars sample return facility issues, noting that machinery for sample analysis will be very expensive for MSR. Some of the machines are many millions of dollars. Is NASA planning for this? Dr. Rinehart said that he assumed that this target \$5M/year budget could fit such expenses over multiple years of funding; it will allow us to do some things but not everything, and will be discussed going forward. Dr. Hurley commented that \$5M buys you two state-of-the-art sample analysis machines; one also must take into account the number of users. This will require a broader approach. Dr. Rinehart said that funds will also be needed to pay technicians to maintain facilities, etc., and agreed that it will be tough, and that some course corrections would have to be made along the way. Dr. Britney Schmidt commented in light of the discussion on sample preparation, noting that there are a lot of issues in ground-based support, lab exercises for instance: is a new policy needed to cover all these activities, and could this additional cost be addressed in the DS as they consider long-term costs and forecasting? Dr. Glaze noted that this was a very good point, and thought the DS should be taking a comprehensive and realistic look at mission costs to enable NASA to support the recommended missions. The other issue for the DS to look at is the number of people served by new instruments, and community access to data.

#### Mars Exploration Program

Mr. Jim Watzin presented an update on the Mars Exploration Program (MEP). The MEP is healthy and productive, making good progress, has a strong and growing collaboration with international partners, and is actively working MSR, as well as Moon and Mars exploration activities. The Mars 2020 (M2020) flight elements have been shipped to Kennedy Space Center (KSC), and the mission is Green across the board. The sample hardware is to be installed as late as possible in order to preserve cleanliness of the payload. The mission is still carrying adequate schedule reserve for the launch scheduled on July 17, 2020. While the FY2020 had been overstressed, M2020 costs have stabilized as well. The cost issues required austerity across the portfolio; R&A was protected, but every other element was affected.

Despite the most recent Senior Review outcomes, remaining support for Mars Express is being wound down. FY21 has been extremely favorable for Mars, but not for extended missions. Mars Odyssey, for example, is at risk of closeout in 2021. MEP has funded two new mission initiatives: Mars Ice Mapper (MIM) and Mars Sample Return (MSR). is a joint CSA/NASA Exploration initiative to map the near surface ice reservoirs primarily in the mid-latitudes with a new reconnaissance orbiter. SMD/PSD/MEP was asked to lead the effort due to their extensive robotic mission experience at Mars. The Canadian Space Agency (CSA) will provide a polarimetric L-band SAR tuned specifically to characterize the ice deposits and their overburden regolith. MIM will help to prepare for 2030s Mars human exploration. Implementation assumes major international and commercial partnerships going forward, and assumes a five-year development cycle. MIM would fly in 2026 to support exploration activities in the 2030s. MIM would focus on regions equatorward to 40 degrees and collect data to inform sites for an eventual crewed

landing. There will be more information about MIM and MSR at the next MEPAG meeting, scheduled for 15 April.

MSR assumes a six-year development cycle, and also targets a 2026 launch date, with samples to be returned in 2031. The mission has made substantial progress, and is transitioning from study to implementation. A campaign concept review is scheduled for June 2020, and Key Decision Point-A (KDP-A) for August 2020. Two Launch Readiness Dates (LRDs) in late 2026 are the first of two opportunities to take advantage of favorable orbital mechanics. MSR Campaign mission elements include the M2020 Rover, a sample retrieval lander with Mars Ascent Vehicle (MAV) (July 2026) to land in Jezero Crater; and an Earth Return Orbiter (October 2026). Returning samples will descend to a remote range location in the US. MSR campaign elements have been strategically aligned between ESA and NASA, and assignments have been made across NASA centers. The MSR Campaign timeline will be examined in greater detail at the April MEPAG meeting. All-solar power is being planned for Mars surface activities in 2028 and 2029, with 13 months being the nominal length of surface activities. The pre-phase A schedule for MSR has been managed well so far.

Dr. Michael Meyer, MEP Chief Scientist, addressed two major activities occurring at the programmatic level: planning for MSR in the Mars Science Planning Group (MSPG), and the Mars Architecture Strategy Working Group (MASWG, which considers other Mars activities). Mars Science Laboratory (MSL) will continue to have Participating Scientists, largely extending those currently in the program, at a lower budget during the extension.

MSPG held two recent workshops, one on science in containment, and one on contamination control. Both reports are available online. MSPG also wrote a Science Management Framework that will address transparency and science maximization. Dr. Meyer thought MSR would need international participation in the eventual science management structure.

A TOR and charter have been created for the MASWG, which will examine what could and should be done in the MEP, other than sample return. The Working Group will consider cubesats to be included through New Frontiers and Flagship missions. MASWG has had two meetings to date; the third one will be in April, with a full report to be completed by the end of August 2020. MASWG has requested and received (53) mission concepts from the community and has been given briefings on key programmatic and technology issues and will be conducting videoconferences between now and April. The April meeting will start to flesh out the eventual product of the MASWG, and produce written results in time to feed into the DS process.

Dr. Meyer presented some Mars science highlights. The Mars Reconnaissance Orbiter (MRO) revealed through sounding radar ancient remnants of the Mars northern polar ice cap. MRO's Hi-Rise instrument has also enabled understanding of Mars southern polar ice layers, their thickness, and the history of their deposition over the last 30 million years. The Mars Climate Sounder has looked at surface temperatures that allow ice deposits at the lower latitudes; these are areas at approximately 35 degrees N, the most southerly ice identified thus far near the Mars surface. The Curiosity rover is now sitting atop the Greenheugh Pediment, where it will be able to reveal evidence of real change in the climate of Mars. The Pediment area represents a major change in climate history; researchers think this layer used to cover the entire Gale Crater.

Asked if the MIM mission was to be directed or competed, Mr. Watzin said it was largely a directed mission, with the primary payload being the CSA-contributed radar. MIM has not completed mission formulation studies, thus there may be elements that can be competed. Dr. Verbiscer asked if there were final data on the disposition of Mars Express. Dr. Glaze said she would close this issue out with Dr. Verbiscer and the PAC.

## Lunar Program

Mr. Steve Clarke, presented an update on the Lunar Program, beginning with the CLPS. NASA now has a total of 14 providers on contract, who are eligible to bid for delivery task orders. The most recent providers have been brought on for advanced lander capability: Sierra Nevada, Blue Origin, Tyvak, SpaceX, and Ceres Robotics. The first task orders went to Astrobotics and Intuitive Machines. These companies will provide in-line technology demonstrations for lunar payload deliveries in September and October 2021, respectively. The next TO, 19-C, will deliver Lunar Surface Instrument and Technology Payloads (LSITP) projects and some NASA-Provided Lunar Payload (NPLP) second copies, targeted to a lunar pole site in late 2022. TO 20A is the delivery TO for VIPER; NASA is expecting proposals back on 10 April, to be awarded mid- to late May, for delivery to the lunar surface by late 2023. NASA has also asked for an accelerated option for mid-2023. TO 19D will deliver additional payloads from LSITP, targeted to a nonpolar location in early 2023.

The 2021 CLPS delivery manifests include a number of science, technology, and exploration payloads, and some joint HEO/STMD payloads. In particular, NASA is interested in the performance of Intuitive Mechanic's liquid oxygen (LOX) methane engine. Instruments will ride along to learn about its performance in-flight. A provisional 2022 CLPS delivery manifest includes targets at polar regions and Crisium. The goal for the 2020 manifest is to go to one polar and one nonpolar site each year (such as far-side sites).

Mr. Clarke gave an overview of the Payloads and Research Investigations on the Surface of the Moon (PRISM) initiative. NASA held an open RFI in March 2020 with the intent of developing a catalog of instruments that will aid in determining future landing sites for CLPS deliveries, and will help to move to a more Principal Investigator (PI)-driven cadence of launches. PRISM is looking for high-value, location-agnostic instruments to gain significant science data, and is intended to produce a catalog to feed TOs in 2023 and beyond. PRISM is anticipated to have Participating Scientist Programs (PSP) for each flight. There will be subsequent calls to ask for destination-agnostic and stand-alone instruments. Dr. Ben Bussey added that the Lunar program is aware of proposal review fatigue, and is trying to help the community to efficiently focus their efforts.

Lunar Trailblazer is a SIMPLEx mission now going through phase A/B; it is a lunar orbiter that is designed to study lunar volatiles and perform thermal mapping, perform significant science on small platforms, and address key DS questions. The lunar mobility strategy will be pursued through parallel development paths, with the primary objectives being to get ground truth on volatiles via long-duration operation. NASA is talking to ESA and CSA as potential participants, and has issued an RFI to industry, particularly to non-traditional companies (Ghost Robotics and Boston Dynamics, e.g.). The RFI has had 38 responses. HEOMD, in parallel, has released an RFI for a lunar terrain vehicle that will provide an unpressurized rover for crew.

Gateway science opportunities: the leading approach at present is a space weather (SW) science instrument suite. The Heliophysics Science Division (HPD) is looking to use Gateway to better understand solar wind and energetic particles, and to improve modeling and SW forecasting. The latter would aid in better predicting solar events for both future Mars and Moon crewed exploration. Regarding Deputy Associate Administrator for Exploration (DAAX) internal and external engagement, the DAAX Program Scientist is a member of the Human Landing System (HLS) Source Evaluation Board, thus ensuring ties between directorates. A SMD/HEOMD/STMD workshop that was to be held in Denver in April has been postponed due to coronavirus. The Lunar program is also talking with ESA about communications relay elements at Gateway, and is also talking with S. Korea and JAXA about flying instruments on CLPS flights.

Dr. Brad Bailey presented details on science that is achievable by CLPS, derived from a number of community documents such as the Lunar Exploration Analysis Group's Lunar Exploration Roadmap, and the National Academies' Decadal Surveys. A number of common scientific themes have emerged, such as the study of planetary processes, understanding volatile cycles, the impact history of the Earth-Moon system, and a record of the ancient Sun, preserved in the lunar regolith. Science for 2024 will be enabled by polar landers and rovers, and nonpolar landers, and will help to advancing beyond the Apollo program through field geology, collection and return of new samples, as well as surface instrumentation.

Dr. Hurley noted that a lunar communications relay would be enabling for science, and asked about ESA options for such relays. Mr. Clarke said he was trying to move forward with ESA, and spoke with them almost weekly. Mr. Clarke also has an action, to be discussed across the directorate, to examine in-house, commercial and international options for relay; these discussions should develop over the next 60 days. Italy and SpaceX present some possibilities. Asked a general question about Mars sample collection, Mr. Watzin noted that NASA plans to have redundancy for sample return: M2020 is designed to core and sample, and to leave sample caches behind to be picked up at a later date. There will still be sufficient power in M2020 in 2028; thus, it is a good asset that will be able to deliver to the MAV, in the case that the planned fetch rover cannot carry out its mission. The hope is that M2020 will be able to explore Mars over a seven-year period. Dr. Tim Lyons commented that there are those who wish M2020 could roam as far as possible; how universal is the consensus on where M2020 should go? Mr. Watzin that it is expected that many calls will be made during the mission, and that judgements would be made that will bring the best value. There will be operational flexibility. Dr. Aki Roberge asked about the status of contamination control on the M2020 sampling system. Mr. Watzin said that a main goal of M2020 is to keep the sample chain free of contamination both in terms of PP and any organic contamination that might jeopardize science results, and testing/control regimens are being carried out as a matter of course.

#### Planetary Defense Coordination Office

Mr. Lindley Johnson gave a status of the Planetary Defense Coordination Office (PDCO), which searches for, detects, tracks, and characterizes Near Earth Objects, as well as plans and coordinates for assessments and potential mitigations of potentially hazardous objects. PDCO has two current flight operations: it continues to operate NEOWISE, the "warm" phase of the Wide-field Infrared Survey Explorer (WISE) mission, that is expected to exceed useful temperatures in August 2020; and DART, a mission in development that is on track to launch in July 2021. DART's Integration Readiness Review (IRR) will occur on 11-12 March. DART will be accompanied by an Italian cubesat that will image the impact at asteroid Didymos B. The real observation platform for DART will be terrestrial optical and radar assets, that will be deployed to understand the impact. ESA has now approved the Hera mission to the same asteroid system, which will arrive after the DART impact, where it will be able to collect post-impact data, adding value to the DART mission.

PDCO's other major activity is in developing the space-based survey capability, based on a NAS recommendation to pursue a space-based, mid-infrared telescope designed for discovering NEOs, in conjunction with existing assets, to meet the George E. Brown Near Earth Object Survey Act requirements. Data from this telescope are to be archived for both planetary defense and science purposes. NASA is pursuing a budget to get this mission to phase B. The NEO Surveillance Mission (NEOSM) is expected to benefit from the NeoCam study and instrument development effort, and is expected to cost \$500-600M, including launch vehicle (LV). A Launch Readiness Date (LRD) of 2025 is planned, and the telescope is to operate for 10 years, during which it will be tasked to find 65% of potentially hazardous asteroids (PHAs) over 140m in size, with a 10-year mission goal to discover 90%. NEOSM will produce sizes from IR signatures, compute the cumulative chance of impact over the next century for PHAs more than 50m in size, and comets. The mission will also deliver new tracklet data on a daily basis to the Minor Planet Center. The observatory will be designed to be compatible with Falcon 9 or Atlas 401 LVs, operate in a Sun-Earth L1 halo orbit, and to use the Deep Space Network (DSN) for

telecom and navigation. Data will be collected, analyzed and archived at the Infrared Processing and Analysis Center (IPAC) at the Jet Propulsion Laboratory (JPL). The NEO Surveyor Flight Project will be directed to JPL as well. Mr. Johnson provided a brief description of the NEO Surveillance Mission Management Structure.

Dr. Kelly Fast provided an update on current PDCO statistics. The total number of near-Earth asteroids (NEAs) is over 22,000, with 2000 characterized as PHAs, with 157 of these latter PHAs having a diameter of over 1km. Near Earth Comets (NECs) number 109. There were 2431 NEA discoveries in 2019, with 560 detected so far in 2020. The discovery rate of NEAs of 140m+ seems to be leveling off with current observational capabilities; there were 524 discoveries in 2019, and 102 so far in 2020. Progress in 140m and larger is defined against a total population estimated to be about 25,000. In 2019, there were 77 close approaches (defined as within one lunar distance). Twenty-four of those objects were larger than the asteroid that is believed to have caused the Chelyabinsk event (20m). Two of those objects were over 100m in size (one of which passed at 0.2 lunar distances from Earth).

Signatories to the International Asteroid Warning Network (IAWN), currently 25, include ESA, Colombia, Croatia, and amateur astronomers. Every year, IAWN reports to the Committee on the Peaceful Uses of Space (COPUOUS) at the United Nations. Dr. Fast detailed some changes in ROSES20 related to planetary defense: SSO will contain only the scope of what was the previously the Planetary Astronomy component. There will no longer be a NEOO component; this will now be solicited through the newly named YORPD component: this will include NEO survey operations, NEO science, and impactor threat mitigation studies. Dr. Roberge asked about management lines of authority: who is in charge of what decision? Mr. Johnson said that much like other planetary missions, NEOSM as a flight project will be governed by the same management structure as other planetary flight programs, reporting up through Marshall Space Flight Center to PSD. Dr. Roberge asked: is the Survey Director a systems engineer? Mr. Johnson said that since NEOSM will be an operational mission, it will be managed by a Survey Director, equivalent to a PI. Dr. Roberge asked: who has the authority to decide Level 1 hardware changes? Mr. Johnson said that Level 1 requirements are drafted by Survey Director and coordinated with the PDCO.

### PDS

Dr. Tim McClanahan provided a dual briefing on the Planetary Data System (PDS). PDS was established in 1989 as a formal Planetary Data Archive to collect and curate planetary data. PDS Level 1 requirements are levied by Headquarters. PDS makes all planetary data sets available, and its content is maintained on-line. User community needs are evolving, as well as data technologies; the PDS configuration is maintained through primary nodes, subnodes, and data nodes. The PDS Project Office is housed at Goddard Space Flight Center (GSFC). The PDS Archive contains 1.85 PB (petabytes) of data and is growing, representing about 70 missions, and 2000 data sets from 600 unique instruments. Data content is expected to increase greatly in 2020 from lunar R&A and communications from deep space. Active US missions served by PDS are largely Green.

Some exceptions: Juno is Yellow; its data deliveries have been behind schedule. The Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) has experienced some delays due to health issues with a key team member. The evolving data environment includes the science community feeding back into PDS, curation, cartography, and the NASA Space Science Data Coordinated Archive (NSSDCA). PDS is beginning to use cloud computing. Users and methods are also changing. Current PDS issues include increasing data volume from lunar activities, greater complexity of instruments and data, more user interfaces, archive usability, the need for internationalization, the integration of a federated system, increasing IT security threats, and new technology opportunities (cloud computing and machine learning), all of which must be balanced against constrained funding. PDS continues to act in congruence with the recommendations of the Planetary DS 2013-2022.

PDS R&A growth has resulted in part from an increasing data stream from ROSES. PDS is moving forward on modernizing the data sets through adaptation of PDS4 data standards, and improved training. A 2019 white paper was written on the development of standardized search APIs. A PDS 2020 Strategy for Data Management and Computing for Groundbreaking Science document highlights four areas: open data/open software; high-end computing; archive modernization; and advanced capabilities. PDS3 to PDS4 migration continues to be a top priority; most data is in PDS3, 65% of which comes from the Lunar Reconnaissance Orbiter (LRO). Migrations are planned over the next few years. Migrations in progress include Cassini and Viking data. IPDA international partnership; includes China, et al. Cloud computing – initial cloud deployments, developing a PDS white paper on the subject, to provide to the Strategic Data Working Group.

Dr. McClanahan summarized the briefing, and encouraged the community to respond to the PDS Survey on user needs (URL is <https://www.surveygizmo.com/s3/5308511/>).

### PDS HQ

Dr. McCauley Rench provided an overview of PDS activities at Headquarters, in her capacity as the Program Scientist for PDS. PDS is considered the “trusted repository,” and NASA wants to ensure the continuation of this reputation as its first priority. Another Headquarters priority is the migration from PDS3 to 4, and a third priority is data discoverability and usability, unified search capabilities, and higher level data products.

PDS nodes are scheduled for review, thus NASA has delayed the Senior Review until it completes a larger scale review of PDS, using as a basis the recently completed report, Strategy for Data Management and Computing for Groundbreaking Science 2019-24. NASA recognizes that there are many components of PDS, and would like to have an independent body review the “ecosystem,” to identify gaps and redundancies. The PDS Ecosystem Review will have four sub-panels, and will consider open software and open tools, among other subjects.

### Findings & Discussion

Dr. Roberge asked about a NEOSM management plan. Dr. Mainzer’s understanding was that her office would be coordinating and developing requirements, working together with PDCO to develop them. Resource-constrained trades will also have to be considered. She reiterated that project management would be run through MSFC, and added that the survey team would be equivalent to a science team. Yes, there is an investigation team and a flight element team. Dr. Glaze noted that the NEOSM organization has been reviewed and agreed to by all parties, all the way up to PSD and SMD. Dr. Verbiscer requested that PAC receive an update on the 2020 Senior Review, and what the role of the PAC would be for the 2020 Senior Review (SR). Dr. Glaze said that PSD had just released the final call for SR 2020. The two missions under review will be InSight and Juno. New Horizons will be in the 2022 SR. Dr. Glaze reported having received a lot of feedback about the complexity of the last SR structure, leading to PSD holding a Lessons Learned meeting with the participants, including the chair of the SR subcommittee. The primary conclusion was that PSD needs to move away from the structure. At the same time, HPD was setting up an SR in such a way that the results could be directly reported back to the PSD. The intent is to report out these Lessons Learned to the PAC. PSD anticipates the ability to move more quickly in the future by removing some bureaucratic obstacles.

### General comments

Dr. Britney Schmidt asked about the potential impact of the Artemis program on the science budget. Dr. Glaze said that the proposed PBR21 budget outyears should be taken with a grain of salt. There is much collaboration between SMD and HEO to ensure that science remains strong in the Artemis endeavor. The FY21 budget is very strong for Planetary, as well as for the

entire SMD. The amount proposed for Planetary Defense in 2021 is the same as it was in 2020. In addition, PSD has received much support for MIM and MSR. Regarding the MIM, Dr. Glaze noted that MIM will be considered by DS, provides a unique opportunity, a potential collaboration with Canada, and potential work with other partners, including commercial. The new orbiter would also answer the need for replenishing the aging communications infrastructure around Mars.

Dr. Mainzer asked about the potential impact of carrying two LVs on the Europa Clipper mission. Dr. Glaze commented that she has this discussion daily, and that there is an impact as the Critical Design Review (CDR) approaches. The issue is not only time-consuming, but it also makes it difficult to finalize the mission design. However, the decision is far above the level of PSD. NASA is currently required by law to use SLS for the Clipper. PSD is exploring a number of avenues to remain consistent with the law. Dr. Glaze advised the community to stand by as the discussion evolves, and that it was important to note that Headquarters is fully aware of this issue, and of the full magnitude of the impact of carrying the two LVs.

Dr. Verbiscer queried the PAC on potential findings. Dr. Lyons commented that he was surprised and concerned to hear that some portion of the Mars sample caches destined for MSR would be stashed on the M2020 and some on the surface. He worried that this sort of regime might compromise the *in-situ* capability of M2020, and wanted to hear more input from the community and what they think about this. Dr. Glaze noted that Dr. Meyer had indicated that there will be a science group that includes M2020 and planning for MSR in its purview, which will aid in driving these decisions. She didn't think any of these things are completely decided, and that all aspects of the mission would be weighed against operations for M2020. Asked to what degree would these elements be reviewed by the DS, Dr. Glaze quoted the statement of task for the Planetary DS (available on-line). Essentially, the quote is: "MSR should be reviewed by DS in all aspects." PSD has also asked the DS not to prioritize MSR against other missions.

Dr. Roberge asked if there were enough witness samples for the canisters in the (MSR) sample collection systems, and if the entire process was being evaluated. Dr. Glaze noted that Dr. Pratt is heavily engaged in this process; Dr. Rench added that there is also a team wholly devoted to this. Dr. Pratt is completely independent from SMD, as she is part of the Office of Safety and Mission Assurance (OSMA). She is concerned with both PP and any compromise to the science. Witness samples will continue to be taken until launch. Dr. Hurley asked if Dr. Meyer was considering sample distribution, and any integration with Johnson Space Center (JSC) and the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM). Dr. Glaze said her understanding was that sample curation planning is under way, and that she would ask Dr. Meyer to address the question the next day. She did know that the samples will be curated in the US, while NASA continues to develop an approach with both JSC and with Europe to get to an equitable distribution.

Dr. Verbiscer noted that Dr. Jeff Grossman had requested a written question on the MSR issues. Dr. Roberge asked if there were a budget in place to actually start building the NEOSM. Dr. Glaze answered that, assuming PDCO is funded at the \$150M level over the next several years, it will allow NASA to target a launch for 2029. If additional funding comes in, NEOSM can launch sooner. NASA is still in the process of getting an Operating Plan approved, and some numbers in the enacted budget may change. The \$150M covers the entire PD program; when DART launches in 2021, its funding will roll off the budget line. Addressing the evolving coronavirus situation, Dr. Glaze noted that NASA is trying to get Town Halls (R&A, Agency Night, and DS) virtualized, and schedule them to accommodate most time zones. The Agency is also moving all panel reviews and other meetings to virtual as long as necessary. Justin Hagerty said he appreciated the efforts on the review of the PDS ecosystem and felt it was worth a PAC finding.



Tuesday, March 10, 2020

Dr. Rinehart opened the meeting.

### Exoplanets in our Backyard

Dr. Noam Izenberg presented on a February 2020 workshop in Houston, TX, entitled Exoplanets in Our Backyard (EIOB). The Venus, Outer Planets, and Exoplanet Analysis Groups (VEXAG, OPAG, and ExoPAG) coordinated the meeting. The premise grew from an “off-season” meeting of VEXAG, with the idea of Venus as the Exoplanet Next Door, or Solar System Ice Giants as Exoplanets in our “backyard,” to take advantage of cooperative action of the three AGs regarding exoplanets and Solar System synergies on planetary properties, evolution, and habitability. Major topics included comparative planetology on worlds near and far, lessons learned on planetary statistics, etc. The goal of the meeting was to foster new collaborations among scientists in the Solar System and Exoplanet communities. There were a number of standard sessions with talks on focused topics, with speakers convening in a panel, a very successful format. There was also a NASA Headquarters Town Hall, an “unconference,” and one-minute “lightning talks” in the poster session. Working lunches were held on all three days. The meeting concluded with a final day review for developing findings and action items. EIOB held a public talk at Space Center Houston on Exoplanets (about 150+ attendees, including many science teachers from a local conference). All talks are now available up on the LPI website. The meeting had 111 total registrants, with 80-100 in attendance throughout the three days. The organizers are very pleased about the representation in the communities. The participants skewed younger and more diverse. The meeting accepted 82 abstracts, 30% of which had females as first author, and 33% with persons of color as first author. Dr. Izenberg felt that similar gatherings could serve as career-defining meetings for some young scientists. In an informal poll of attendees, almost everyone reported having generated new ideas or collaborations. An after-meeting survey, for which about 30% responded, rated science content as generally good to excellent); 2/3 of responders said they had made new connections and started new collaborations. There was also much enthusiasm about the meeting format, seen as better than the “classic” format. Basically 100% of attendees were interested in having a similar multidisciplinary conference within a year or two.

EIOB was notable for the interdisciplinary nature of its presentations, and for providing an opportunity to overlap with scientists from other fields. Going forward, it has been proposed that the next VEXAG “off-season” meeting would be a follow-on (EIOB-II), potentially adding other foci like lab and field studies. AG leadership is discussing the idea and wants to get Headquarters buy-in. They are still building the organizing committee, and may want to grow the organizations that are actively involved. The findings and action items from EIOB-I will feed forward. And will probably lead to a submission for an AGU Special Session, as well as a white paper to the DS. Dr. Roberge asked how the conference managed to avoid field-specific jargon. Dr. Izenberg said the intent of the first three talks addressed this topic, and spent time introducing the language of the various specialties to this science-educated, but not specialized, audience. This foreknowledge smoothed things out, and paved the way for excellent questions, giving some early careerists the opportunity to ask important questions as well.

### Astrophysics Assets for Solar System Observations

Dr. James “Gerbs” Bauer gave a presentation on a study of the use of Astrophysics (AP) assets for planetary science, which had been conducted by a committee of the Small Bodies Analysis Group (SBAG), in order to compile a uniform set of capabilities that would maximize the yield of Solar System science with future AP assets (which also resulted in a white paper for the AP DS). The committee was selected for a balance of experience and expertise. The study also solicited input from the community, including a call for input via a webform. The motivation for this effort is many-fold. Missions will benefit as well as the Planetary Science research community; e.g. researchers can take advantage of a compilation of Solar System orbits (excluding exoplanets) assigned to planetary. The AP asset, the Hubble Space Telescope, is responsible for about 15% of papers that represent a significant contribution

to planetary science on the subjects of small bodies, giant planet auroras, e.g.). Other AP assets can play a similar role.

The study identified compelling subjects of study, identified key capabilities needed, the range of platforms and payload criteria that span the populations, and gaps in instrumentation and architecture. Examples of science drivers and capabilities include research on Planet IX, and comet deuterium/hydrogen ratios. Most compelling was the incorporation of non-sidereal tracking (NST) capabilities; failure to accommodate NST impacts the ability of platform to serve the needs of planetary science. In addition, planetary research would benefit from large dynamic range coupled with increased sensitivities, and rapid readout. Modes of rapid read-out would allow for averaging over co-adds, e.g. and would facilitate observation of planetary occultations.

Large fields of view (FOVs) are of use to planetary and AP surveys alike, but there are limitations that were noted by the committee. Another major capability is scheduling and MOS-GDS. Information relevant to Solar System observations needs to be emplaced in the metadata, and missions overall would need accurate station-keeping. The study also ranked enhanced capabilities and benefits in terms of how each community is impacted.

Conclusions from the study:

- Planetary Science-enabling capabilities should be considered early in the design.
- Planetary Science capabilities must be weighed in the balance of the overall platform capacities.
- Small alterations should be considered with other science goals for their impact on the Planetary Science usage cases, such as:-Flexibility for marginal alterations of wavelength
- For surveys, appropriate cadence considerations for surveys.

#### Solar System Science with the James Web Space Telescope

Dr. Heidi Hammel presented a briefing on planned observations in planetary science, first introducing Dr. Stefanie Milam, James Web Space Telescope (JWST) Deputy Project Scientist for Planetary Science. JWST originated with four science teams: first light and reionization; assembly of galaxies; birth of stars and protoplanetary systems; and planetary systems and the origin of life. Planetary science has been a key JWST theme from its beginning. JWST will be at the L2 position between Earth and Mars. It will not be looking at Mercury, Venus, Earth or the Moon, but it will see everything else. JWST will have a very high spatial resolution; it is not a UV/blue telescope like Hubble, but works from the red (0.6 microns) all the way out to 28 microns. Imaging and spectroscopy will be useful to the entire planetary community. JWST has a Level 1 requirement for non-sidereal tracking, and its ability to track up to 30 milliarcsec per second allows it to track just about everything in the Solar System. There are saturation limits for the bright planets (Mars, Jupiter, Saturn, Uranus, Neptune), but JWST can do imaging work on these planets as long as the study is selective about modalities.

Some types of JWST proposals are Guest Observer (GO), Archival (AR), Guaranteed Time Observations (GTO), and Director's Discretionary Early Release Science (DD-ERS). Investigators in the GTO program were selected in 2003, including four instrument teams. DD-ERS is designed to get information to the community quickly. In the GTO program, there has been interest in KBOs since the early days. Of the six JWST interdisciplinary scientists, two were Solar System scientists (Dr. Hammel and Dr. Jonathan Lunine); each will have ~100 hours of guaranteed time on JWST. Of the 13 DD-ERS proposals, one was for Solar System science: a program led by Drs. Imke de Pater and Thierry Forget focused on the Jupiter system. The DD-ERS data will be available in the Archive immediately. Dr. Hammel said that most data from her group would also be available immediately, save for some data on KBOs. Dr. Mainzer asked if time allocation was determined by the number of proposers or number of hours. Dr. Hammel said that time allocation was actually based on an average of the number of hours requested and the number of proposals.

Dr. Hammel provided a taste of planned science from her group. JWST will provide excellent IR spectral resolution for Mars, including NIRSpec's capabilities to detect deuterated water (HDO), and also organics on Mars. Asteroids will also be viewed spectroscopically by some JWST scientists, and could include views of interesting spectral features that are blocked by Earth's atmosphere. For Jupiter, JWST's 5-micron window may provide data on possible signatures of chromophores, stratospheric structure, access to fresh ice material, and data on ammonia, ethane, and phosphine. JWST will be able to get some spatial and spectral resolution to study seasonal hemisphere changes on Titan, as well as to perform comet spectroscopy and imaging. JWST will be able to spectrally characterize almost every KBO discovered to date.

GO Cycle 1 proposals are due on May 1, 2020. Launch is still scheduled for 2021. Allocations are available for small, medium and large programs. Dr. Hammel encouraged the community to propose, and added that archival research for Solar System from her team will be available. There is more information at the JWST user documentation website, which includes training events and contact names. Dr. Roberge asked if there would be Theory proposals? Dr. Hammel said, that Theory, Calibration, and all the standard types of proposals that NASA has had for Hubble will be available for JWST.

### Mercury Group

Dr. Carolyn Ernst presented a study on recent efforts to create a Mercury Analysis Group (MExAG). Terms of reference (TOR) have been drafted, and there is now a listserv. While not an official AG currently, community involvement is being cobbled together. An *ad hoc* committee that was created in Summer 2019 produced a 9-page report as input to the next Planetary DS. The report content included big-picture questions such as: how did Mercury form, how did it evolve. The community has also put together 4 white papers, now listed on the LPI website: Mercury's low-reflection material; the importance of the Senior Review process; opportunities to explore solar deposits in PSRs; and a case for Mercury landed science (the next priorities for robotic exploration of Mercury). While the LPSC 2020 meeting has been cancelled, Mercury 2020 is still scheduled for June 2020 in France. This event will cover exploration of Mercury up to BepiColombo; registration is capped at 121, with 7 on a waiting list. A Mercury Lander Mission Concept Study is under way, run by an interdisciplinary science team with diverse experience. An engineering study will begin at the Applied Physics Laboratory in late March that will look at trade studies to develop a robust payload concept. This information has been shared this with the Mercury listserv in order to ensure community input, and the proposal has been made available to the public. Initial planning is well under way. The future MExAG will present at the Planetary Mission Concept Studies Workshop, which has been moved to a virtual meeting in April. The final report due on June 30, which will feed forward to the DS committee.

Dr. Ernst presented questions for the PAC: what is time frame for the creation of MExAG and its inaugural meeting? Will there be a future solicitation opportunity for US scientists to participate in BepiColombo after the initial three-year appointments? Will there be a way to support a higher participation rate? Dr. Glaze said PSD wanted to kick off the AG in early Summer, to have the MExAG in place by late Summer, early Fall. As to BepiColombo, Dr. Glaze emphasized that it is an ESA/JAXA collaboration, with NASA supplying the Strofio instrument, and DSN support. In return, NASA was provided three slots (one IDS and two GI). There was a great turnout in proposals, on both Mercury and the Venus fly-by. ESA announced that it will put out another solicitation once the spacecraft has arrived at Mercury.

### VEXAG

Dr. Darby Dyar presented an update on the VEXAG, which has added three new people to the Steering Committee, and has said goodbye to a few members. The AG has established a new six-month rotation schedule, to specifically require having a 30% constituency of early career investigators on the Steering

Committee at all times. VEXAG has appointed “Nugget Officers” to help Venus become more visible at Headquarters by reaching out to authors of significant papers. The AG has also created a Committee Organization Document Committee; a working group to plan the next “off-season” VEXAG meeting in 2021; a working group for the next VEXAG meeting in November 2020, and a VeGASO committee.

Near-term goals of the VEXAG are to provide support for the DS; build a Venus program through community engagement; improve communication; have open meetings and public forums; expand the visibility of Venus science at conferences and at NASA; and support the recent selections of Venus missions for Discovery and New Frontiers programs. A Venus Strategic Plan, published in 2019, led to the DAVINCI mission concept, focused on the study of ancient oceans on Venus and the evolution of habitability, as well as the VERITAS mission concept, that includes radar and spectroscopy for mapping Venus. Next drafts are due in November 2020. The Venus community is united behind these missions.

VEXAG has also received funding to study a Venus Flagship mission (habitability assessment). The 2020 Venus Flagship Mission Study (Gilmore, et al.) will consider a mission designed to launch in 2031, at a cost of \$2B. The mission would study orbiters, small satellites, 30-day balloon, and a long-lived lander. VEXAG is also supporting an ongoing study on a Venus Surface Platform; four subgroups have been tasked with a draft report and white paper, both of which are currently in review. The next VEXAG meeting is scheduled at Caltech on 16-18, November, 2020; it will be focused on mission summaries of Solar Orbiter, Parker Solar Probe, Akatsuki, BepiColombo, ISRO, and various ride-along opportunities. The meeting will employ a new format that will include technique tutorials on high-temperature experiments under Venus conditions, and Venus-like exoplanets. These tutorials have been well received in the past. There will also be poster sessions and a field trip. The new format has been a great community-building exercise. A total of 36 DS white papers had been planned for presentation at the now-cancelled 2020 LPSC, representing numerous different aspects of Venus science.

VEXAG has initiated a Venus Petition to address shortcomings with the current Venus In-Situ Explorer (VISE) New Frontiers priority investigation, and to request a change in the upcoming New Frontiers AO. The petition proposes two new goals to replace the six goals that are currently being considered in the VISE priority investigation, as the community feels that the six goals are too overwhelming for the mission.

Dr. Dyar presented selected VEXAG findings: Of note was a finding on a careful evaluation of US funding commitments to international missions, and prioritization of US missions. In response to another VEXAG finding regarding an opaque budget and limited support, Dr. Dyar reported that the VEXAG had received a response, and appreciated Headquarters attention to the matter. The VEXAG had simply asked that all the AGs be treated the same, and felt that it had been heard. Dr. Dyar concluded with a listing of 2020 Venus-related workshops, commenting that the Venus community seems to be now pulling in the same direction, laying groundwork for a dramatic expansion of the field.

### SBAG

Dr. Bonnie Buratti presented a status of the Small Bodies Analysis Group (SBAG). There have been no changes in its Steering Committee membership since the last PAC meeting. SBAG seeks broad community support for small bodies [asteroids, comets, interplanetary dust, trans-Neptunian objects (TNOs), centaurs, meteorites and planetary defense]. SBAG recently posted its latest goals document, which preserves its three original goals: small bodies, big science; defend planet Earth; and enable human exploration. The new document includes technology and human exploration sections, and while an in-situ resource utilization (ISRU) section had been planned, the community seemed to lose interest. The small bodies missions OSIRIS-REx, Hayabusa2, New Horizons, and Psyche and Lucy, are all coming along, and the community is pleased to note a commitment on NEOSM. SBAG is also following the progress of DART and Hera, Destiny + dust; Mars Moons eXploration (MMX); and Comet Interceptor. SBAG was

disappointed that small bodies were not part of the Discovery selection, but there is some overlap with the Trident Discovery mission (to Triton).

SBAG held its last meeting in January, in which it finalized the goals document and had a workshop on white papers. Dr. Buratti presented SBAG findings that have recurred repeatedly: SBAG has long supported the NEOSM, and encourages NASA to support it at a level sufficient to achieve PD goals as currently scheduled. SBAG also supports continued efforts to broaden the field and enhance diversity. SBAG continues to seek clarification of targets permitted for the New Frontier #5 call. SBAG is troubled by the limited support for the Arecibo facility, and limits on federal workers for international travel. SBAG continues to support the Participating Scientist program, and notes a community concern for software that is not optimized for moving targets. SBAG encourages NASA to support funding for optimized software.

Decadal thoughts and issues: SBAG is tracking 36 papers focused on science goals and targets, and is curating five papers based on its overarching objectives as outlined in its Goals Document. SBAG supports science-based criteria driving the DS. Because overlap exists in many areas, SBAG therefore encourages the submission of joint white papers. Dr. Buratti briefly reviewed specific missions to be mentioned in white papers in broad terms, “big” questions for the decadal report, and SBAG’s pointed support for including planetary defense in the Decadal. SBAG plans to meet again in June.

#### OPAG

Dr. Jeff Moore presented. The Outer Planets Analysis Group (OPAG) is the “comparative planetology” AG. The OPAG charter encompasses the evaluation of Outer Solar System exploration goals, objectives, investigations and required measurements, determined on the basis of the widest possible community outreach. OPAG meets twice per year. Its Steering Committee has welcomed new members since the last PAC meeting. The last OPAG meeting was held in February, followed by the EIOB meeting. Dr. Moore echoed enthusiastic comments of others who had attended EIOB. A Town Hall meeting scheduled to be held in Houston has been cancelled, but may be virtual. OPAG intends to transition to three-day meetings, the next to be held in Seattle in September, if possible. Some key activities since the last PAC meeting have been: Io Volcano Observer selected for further Discovery mission study; TRIDENT, a very exciting exploration of the neptunian moon Triton; Juno completed its 25<sup>th</sup> orbit of Jupiter; Europa Clipper has completed CDR; the ESA mission JUICE is progressing toward a 2022 launch date; three OP mission studies have been selected for DS consideration via ROSES, and an OPAG Committee White Paper has been posted. The New Frontiers program has been very good for exploration of the Outer Planets, as evidenced by the continuing contributions of the New Horizons and Juno probes. The OPAG goals document was updated in August 2019, and included a revised introduction, the addition of recent sections on planets in the Kuiper Belt, Ocean Worlds and the Search for Life, OPAG relevance to worlds not in the OSS, and telescopic observations.

Dr. Moore encouraged PAC members to read the scientific goals for exploration of the Outer Solar System contained in the OPAG goals document, which describes science objectives in detail. OPAG has also formed a new committee to examine priority technologies and technology development, such as miniaturization and life detection instrumentation. Some select findings from January: OPAG is concerned about the fast drain on Europa Clipper reserves; OPAG supports *in-situ* technology development for future Outer Worlds exploration; OPAG requests a report on Icy Satellite technology; and OPAG commends the outstanding success of Astrobiology Institute and the new Research Coordination Networks (RCNs). OPAG is in favor of DAPR, which could be applied to the instrument development program that currently lacks diversity.

Dr. Moore closed with some observations and conclusions from the OPAG Committee White Paper:

- For large directed missions, OPAG’s top recommendation is to complete Europa Clipper, and its top recommendation for a new start is an Ice Giant Systems mission.
- OPAG recommends that NASA study an Enceladus life-search mission, and strongly recommends that the next Decadal Survey include a Priority Question about actual life or biosignature detection rather than just the study of habitability.
- For New Frontiers class missions, OPAG supports opening competition to all solar system destinations, as recommended by the National Academies in 2008, in particular, the inclusion of Enceladus and Titan ocean worlds missions, along with Io Observer and Saturn probes, and exploration of KBO planets.

### MEPAG

Dr. Aileen Yingst, Chair of the Mars Exploration Analysis Group (MEPAG) presented. Regarding MEPAG programmatic, she pointed out that the MEPAG Executive Committee counts PAC member Justin Filiberto as a member. Since the last PAC meeting, MEPAG has had a number of virtual meetings. MEPAG has been discussing white papers, and has also been using Google Docs for more collaborative paper-writing, and to encourage interaction in the community. Upcoming events include a F2F scheduled for April (now entirely virtual), lightning presentations planned on potential white papers for the DS; and a discussion of the federal budget. Release of the MEPAG goals document is a major planned activity. Life, Climate, Geology, and Human Exploration are the 4 major goals addressed in this document. The final version was to have been rolled out at LPSC, but Dr. Yingst felt the deadline would be met despite current Covid-19 issues. Among some additions; supersonic retropropulsion. Some HEO topics have been rearranged around strategic knowledge gaps (SKGs).

Current issues for the MEPAG include the proposed FY21-25 Administration budget outlook. The good news is funding for MSR; an increase in R&A; funding for a MIM study; and some restored support for MAVEN. The bad news is that some continuing Mars missions will have their funding reduced, and two more will be phased out entirely: MSL (in two years) and Odyssey (in one). MEPAG feels that these decisions seem to call into question the value of the three-year Senior Review cycle. NASA significantly reduced funding for Mars Science Laboratory (Curiosity) and Odyssey, despite their high ratings in the Senior Review. Odyssey is the primary communications relay for InSight at present; this situation is particularly worrisome and seems directly opposed to MEPAG findings on the need for Mars communications infrastructure. Future funding cuts for MSL Curiosity are more problematic than NASA would seem to recognize.

MEPAG feels that it is not clear to the community what MIM actually is, and while MEPAG recognizes that such a mission may address science questions in the MEPAG Goals, it questions why it has been funded over other missions identified as higher priority in the Goals document and the DS. MIM does not have transparent vetting; it seems like it is “skipping the queue.” The science intent of MIM is not clear, nor is the funding scenario for MIM vs. MSR.

MEPAG findings that continue to crop up include concern for MSR and beyond. A major finding that recurs is based on the concern about what happens after MSR; there appears to be lack of program definition for other priorities in Mars science, such as polar climate science. MEPAG finds that it is encouraged to see solid R&A support in the FY21 budget. Lastly, MEPAG finds that there is continued concern about communications infrastructure at Mars. Mars Odyssey is 20 years old, but closing it out while it is still functioning is a step in the wrong direction.

### MAPSIT

Dr. Jani Radebaugh presented a briefing on Mapping and Planning Spatial Infrastructure Team (MAPSIT) activities, which recently acquired a new POC at Headquarters, Dr. McCauley Rench. MAPSIT finalized its roadmap in Summer 2019, and is now preparing white papers on data accessibility and useability. The

rationale behind the creation of the roadmap is that spatial data contribute significantly to the success of NASA endeavors. However, spatial data are often not readily interpretable to users outside mission science teams, nor are they processed in standard ways. The roadmap is an effort to facilitate and streamline user access to NASA data. The roadmap can be found at (<https://www.lpi.usra.edu/mapsit/roadmap/>)

MAPSIT is concerned with planetary spatial data infrastructure and foundational data products. An example of a foundational data product is a datum that provides basic positional information on which all other data can be placed; this information is controlled and registered to the body. If we want to land a vehicle or crew on a specific area, we need these foundational data products. They would also be useful for targets like Mercury and Titan. The acquisition of a planetary spatial data infrastructure PSDI will take expertise and time.

MAPSIT examined Europa as a case study, based on a 2018 paper by Laura et al., and consequently proposes that a committee composed of members from OPAG, Europa Clipper, and MAPSIT might be well-suited to consider what products are needed from existing data. The ultimate goal of this exercise would be to have an PSDI clearinghouse to make spatially-enabled data available. It would be possible to take advantage of raw data already on PDS, combined with USGS ortho-rectified data acquired via a PDS annex, for example. In summary, MAPSIT wants to get to an infrastructure that defines policy and standards, people, data and formats, and access, and is trying to figure out how to move forward on this idea. Dr. Radebaugh encouraged PAC to read the roadmap on website, while MAPSIT carries out its intention to start execution on building PSDIs. MAPSIT is also preparing a white paper for the DS, which will be made available on a MAPSIT link.

### LEAG

Dr. Samuel Lawrence, Chair of the Lunar Exploration Analysis Group, presented. In 2018, NASA celebrated the 50<sup>th</sup> anniversary of Apollo landing: 500K people on the National Mall watched the Air and Space Museum presentation. LEAG has been busy, but its 2018 findings are still relevant. LEAG had a successful Lunar ISRU meeting in 2019 and has been hosting relevant papers on this subject on its website. LEAG has been mobilized to respond to the Planetary DS and has stood up a joint CAPTEM/LEAG Strategic Action Team (SAT) on aspects of Artemis sampling and curation. The LEAG report, *New Views of the Moon 2*, is being reviewed, and the LEAG 2020 F2F meeting is still scheduled for September. Dr. Lawrence thanked PSD for its aid in dealing with issues related to lunar sample studies.

The Annual meeting of LEAG was held in Washington, DC in October 2019, focused on preparing for the Decadal Survey and Artemis, and which featured a keynote address from Deputy Associate Administrator, Mr. James Morhard. The LEAG made with eight total selections in the next-generation Larry Taylor and B. Ray Hawke awards, which will help to support future lunar scientists.

In 2019, the LEAG made a number of findings: It is very exciting to be back at the Moon in 2024, but it is disappointing to have only 26 kg of samples; LEAG would support going back to the recommended 250 kg, as suggested in a 2010 CAPTEM-LEAG report, *Review of Sample Acquisition and Curation During Lunar Surface Activities*. LEAG also finds that a permanent American presence on the lunar surface has immense value, and thus strongly supports planning for Artemis Phase 2. LEAG further finds that the VIPER mission is a good first step, and that the Agency needs a Lunar Exploration Program Office. LEAG strongly supports CLPS. LEAG also strongly supports the DS process, but also recommends more flexibility of the science goals be permitted for the New Frontiers #5 call. Lastly, LEAG continues to encourage diversity.

LEAG had a wildly successful virtual meeting in February 2020; the community should expect more of these. The meeting covered Planetary Mission Concept Studies, and an ANGSA update concerning new technologies being applied to the unopened vacuum-sealed Apollo samples. X-ray CT images are already demonstrating order-of-magnitude improvements in understanding.

Dr. Lawrence concluded with a topic of significant concern for the LEAG: in the most resolute and uncertain of terms, LEAG strongly asserts the need for continued inclusion of Lunar Geophysical Network and SPA Basin Chronology Sample Return in the NF#5 opportunity that is to come.

### CAPTEM

Dr. Kevin McKeegan gave an update on CAPTEM, a community-based, interdisciplinary forum, and briefly reviewed the 2020 membership. There have been no meetings since the December PAC meeting. CAPTEM will meet with ARES/curatorial staff on 18 March, and will have more information from its subcommittees at that time. CAPTEM is planning white paper contributions to the Decadal Survey, and is looking for a meeting opportunity to do this prior to the Summer, in light of the cancelled LPSC meeting.

Ongoing issues for the consideration of the PAC include: CAPTEM would appreciate a discussion of emerging plans for Facilities support as part of NASA's response to the NAS report; and will there be new NASA policies on curation of Astromaterials? Also, CAPTEM has questions on how the DS committee is chosen, given an expected increase in sample material over the next dozen years; will there be representation from the sample science community on the Decadal committee? CAPTEM encourages a full discussion on these issues, in order to provide direct input on who is doing sample curation and analysis in advance of submitting white papers.

### Discussion

Dr. Glaze addressed some issues that came up in the AG presentations: PSD has tasked the Committee on Astrobiology and Planetary Science (CAPS), the NAS standing committee that looks at the New Frontiers targets and objectives in advance of the NF#5 call, to provide some limited recommendations. NASA has asked them to look at the Trojan tour and Ocean Worlds, considering recent selections, as well as the new Io Volcano Observer, and Lunar Geophysical Network. She suggested that those who are interested attend the CAPS meeting (31 March— 2 April) meeting. There will be opportunities to at least have some input into the discussion. Regarding SBAG program comments, Dr. Glaze noted that there is a DART PSP that is in the works, and that PSD supports at least 10 PSP programs wherever it can. She added that as SBAG also commented about the appearance that there were no classical small bodies in the Discovery selection, she was curious if they'd thought about what the gaps are, and felt that SBAG should start this conversation about potential gaps to understand future priorities. In addition, Dr. Glaze acknowledged that MEPAG has valid concerns about the Senior Review and how its results are being interpreted. Dr. Glaze noted, however, that budgets are part of the Senior Review decision-making process. Regarding the LEAG finding on Category 1 lunar missions; the programmatic aspect was part of the decision. Dr. Glaze reiterated that Discovery received many outstanding proposals across the board, and Dr. Zurbuchen took the opportunity to increase diversity within the Planetary Science portfolio with his selections. There was no intent to take anything off the table. Regarding the CAPTEM question on how Decadal Survey committee is chosen, Dr. Glaze said everyone has the opportunity to nominate or self-nominate, but the DS runs the show. She strongly encouraged the community to make robust nominations for the DS committee.

Dr. Roberge noted that non-sidereal tracking (NST) had been removed from the Wide-Field Infrared Survey Telescope (WFIRST), which is moving into phase B, and asked if it were possible to restore it. Dr. Glaze said she hadn't talked to APD yet, but thought it was possible to discuss NST. Dr. Roberge asked if SMD could just make the decision to restore NST. Dr. Glaze said that it's a question for the WFIRST team and for APD. Dr. Verbiscer noted that NST had been an issue with JWST (NST was taken

out and put back), constituting another unnecessary roiling of the waters. Dr. Glaze welcomed a finding on the issue.

Dr. Meyer addressed a previous question about who was involved in sample return planning, and explained that the NASA-ESA sample return working group has recognized the importance of JSC and CAPTEM, and that there would there will be appropriate expertise available. A report on an appropriate receiving facility is also coming up. The project's lead scientist has been invited to CAPTEM, and there is an ongoing JPL/JSC effort on witness material. Sample curation will be treated with the same principles it has always been treated at NASA

The committee addressed SBAG and OPAG findings on work force and diversity issues, and the need to get more early-career scientists on missions and proposals, and more women and minorities. There is also a need for more diverse panels on the DS; NASA can push for this. Dr. Glaze noted that NASA had provided an explicit statement on diversity in its statement to the NAS. There is every expectation that the panels will reflect the entire Planetary Science community. It was noted also that there is a cross-AG group working on inclusion and diversity white papers. Dr. Lynne Carter asked if the community would have access to the VIPER project. Dr. Lawrence said that VIPER has not had much publicity, but the LEAG had been pushing for a PSP for a similar mission four years ago. LEAG was consulted about polar resource exploration, and stood up a Strategic Action Team (SAT) to determine what measurements could be made at poles to meet DS recommendations. The community would welcome an opportunity to have more input into VIPER; Dr. Lawrence thought it should be socialized more broadly. Dr. Glaze said she appreciated the line of questioning: VIPER has just been transitioned to PSD, which allows the division to make a more concerted effort on community engagement. Dr. Stroud commented that the community also would like input into the landing site workshop. Dr. Mainzer raised her prior concerns on Europa carrying two launch vehicles, and asked if potential cost increases would not counted be against the Clipper mission. Dr. Glaze said that PSD certainly understands the implications, but it can't manage Congress. When Clipper was confirmed, additional funding to store the spacecraft was identified; trying to communicate this fact outward has been a challenge. She felt that PAC might find it useful to state that indecision is costly.

Dr. Schmidt commented that the Mars community had been surprised by MIM. Dr. Glaze said that there are aspects of science in MEPAG that MIM can address, and that the mission is part of the Agency's Moon-to-Mars priority. She did recognize that it was a surprise, but now the community has chance to vet it. There will be a discussion on leveraging internationals and commercial for MIM, and all these concepts will be discussed in the DS. MIM is a PSD mission, but it is in support of future human exploration. Dr. Roberge asked what would happen if the DS does not support MIM. Dr. Glaze thought that a recommendation against MIM would prompt discussion at Headquarters.

#### Findings and recommendations discussion

Dr. Verbiscer initiated a discussion of findings. She noted that PAC made a July 2018 finding on Internal Scientist Funding Model (ISFM); the committee is still looking for metrics and details, and hasn't been able to find any presentations on the subject. How is ISFM being implemented and how is it affecting the rest of R&A? Dr. Rinehart said that NASA is in the third year of ISFM. In April, NASA plans to provide data on the program in a uniform and easily digestible way. As to ISFM's overall impact on R&A, there has been a reduction in proposals from centers. There have been no significant changes in funding profiles. Dr. Glaze apologized for the delayed response, which is more complicated than it should have been. Since Dr. Rinehart has come on board, he and Megan Thompson have been weeding through the details. By Summer 2020, there should be a report of some sort. Dr. Robin Canup commented that while the PAC felt strongly about having transparency in ISFM, its true concern is really what the science says. It will be important to articulate to the community that this is what NASA is doing. Dr. Rinehart noted

also that ISFM has been doing important community service that enables science. Dr. Rinehart invited volunteers to engage in planned external reviews on the ISFM reports.

In response to a question about MIM, Dr. Glaze reiterated that the mission is in support of HEO objectives, but is counted in the PSD budget. The intent of MIM is to map the distribution and state of the water, as HEO feeds forward to Mars. It is a science mission to lay the framework for (human) exploration. Part of MIM's objectives are driven from previously identified SKG activities for the Moon and Mars. Dr. Meyer added that there is a HEOMD representative on the MEPAG. Dr. Glaze reminded the PAC that MIM is pre-phase A, allowing plenty of room for more conversation about the science, and how it fits in exploration architecture. The DS will play a very important part in understanding how MIM fits into NASA priorities. Dr. Meyer noted that details about radar needs, resources in the subsurface science priorities, etc., were laid out in a report done by MEPAG some years ago. Asked if the upcoming Planetary DS would be destination-focused or science-focused, Dr. Glaze said she had had extensive discussions about this, with the AGs both individually and collectively. Dr. Glaze favored big science questions be specified in the Statement of Task. The DS committee knows how PSD feels about it, but it is up to the NAS. Dr. Glaze expressed her gratitude to the AGs for pulling the questions together so well, as it provided great food for thought at the CAPS meeting.

Dr. Mainzer asked if the guidance for DS white papers still emphasized high-quality papers with more co-authors (vs. many different papers with single authors). Dr. Glaze said the intent of this guidance had been to be sensitive to the readers on the panel. A single paper with many endorsements is as compelling as many papers, and is a more efficient use of the reader's time and attention. The guidance is meant to help community to be impactful in their white papers. Dr. Justin Filiberto asked whether a selection of only one Discovery mission mean that the next selection will be sooner. Dr. Glaze felt this would depend in part on what is ultimately selected, and what the funding profile will be. She wants to select two, and is trying to make that happen. Asked if a finding reiterating support for previous DS recommendations on Discovery cadence would be helpful, Dr. Glaze replied that the PAC should consider the actual costs of these missions, and how much it would truly cost to maintain the cadence.

Asked whether there have been any Lessons Learned about how the midterm reviews can respond to technology development obstacles (such as for *in-situ* capabilities for Venus exploration), Dr. Glaze said that for competed lines, PSD tends to go to high-heritage capabilities. Currently, PSD is looking to see if it needs to make adjustments. Investments in technology however pushes NASA missions. Dr. Glaze felt it was not so much the tech capability, but more about whether the science objectives in New Frontier are still relevant for Venus. It seems the DS can't respond very quickly to new scientific understanding and new technologies; the midterm report was intended to address these things for Venus. Dr. Izenberg commented that the objectives have not changed for Venus since the last DS. The Venus community-at-large feels that this effectively hamstring any valuable Venus mission planning for New Frontiers. This is why there is a petition, to enable the Venus community to respond to New Frontiers #5. Dr. Izenberg asked whether an interdivisional gathering such as the EIOB workshop might be more widely adopted by NASA, bringing together multiple AGs and communities to encourage cross-fertilization of ideas. Dr. Glaze said PSD is very supportive and would be interested.

#### Public comment period

No comments were noted.

#### Wrap-up

The PAC discussed six potential findings:

- Planetary data "ecosystem"
- WFIRST and the exclusion/inclusion of non-sidereal tracking
- Europa Clipper LV finding

- MIM
- Finding on Discovery cadence
- VEXAG technology issue, outdated language in the objectives

#### Questions from Webex chat

Dr. Julie Rathbun was concerned about holding VEXAG meetings in the same location continually, and how this restricted inclusivity and accessibility. There is also some concern based on travel costs, and that some marginalized (such as trans) people may not be comfortable in certain locations, or that there are people who have been sexually harassed at some locations. Drs. Verbiscer and Rinehart felt this was an issue that all AGs should think about in planning future meetings.

Dr. Richard Zurek expressed concern about the two Mars missions being phased out; Dr. Verbiscer thought the issue had been properly addressed during the meeting. Dr. Glaze added that PSD is working the issue, given that appropriations have not yet been made, and is looking to see if it can keep options open on Mars Odyssey. She also noted that the trade space is not infinite, and that some other programs or projects would have to be cut substantially to keep those missions going. Dr. New noted that the Senior Review does get funding information (hence in-guide and outside-of-guide recommendations) expressly to improve the flexibility of the panels to make good, untainted, science-based findings. Dr. Glaze added that PSD tries to provide guidance as best it can against the background of a continuing budget-planning cycle; this is something it wants to do better with the 2022 Senior Review.

#### Adjourn

Dr. Verbiscer adjourned the meeting at 5:30 pm.

## **Appendix A Attendees**

### Planetary Science Advisory Committee

Anne Verbiscer, **Chair**, University of Virginia  
Robin Mihran Canup - Southwest Research Institute  
Lynn Marie Carter - University of Arizona  
Justin Filiberto, Lunar and Planetary Institute  
Chris German, Woods Hole Oceanographic Institution  
Justin Hagerty, United States Geological Survey  
Dana Hurley, Johns Hopkins Applied Physics Laboratory  
Timothy Lyons, University of California – Riverside  
Amanda K. Mainzer, University of Arizona  
Francis McCubbin, NASA Johnson Space Center  
Aki Roberge, NASA Goddard Space Flight Center  
Britney Schmidt, Georgia Institute of Technology  
Rhonda Stroud, US Naval Research Laboratory  
Stephen Rinehart, **Executive Secretary**, NASA Headquarters

### NASA Attendees

Ben Bussey, NASA HQ  
Steve Clarke, NASA HQ  
Doris Daou, NASA HQ  
Elaine Denning, NASA HQ  
Kelly Fast, NASA HQ  
Luke Gezovich, NASA HQ  
Lori Glaze, NASA HQ  
Joshua Handal, NASA HQ  
K.C. Hansen, NASA HQ  
Eric Janson, NASA HQ  
Alana Johnson, NASA HQ  
Lindley Johnson, NASA HQ  
Rebecca McCauley Rench, NASA HQ  
Michael Meyer, NASA HQ  
Michael New, NASA HQ  
Sarah Noble, NASA HQ  
Lucas Paganini, NASA HQ  
Noah Petro, NASA HQ  
Lisa Pratt, NASA HQ  
Louise Prockter, NASA HQ  
Mitch Schulte, NASA HQ  
Tom Wagner, NASA HQ  
James Watzin, NASA HQ

### Non-NASA Attendees

Joan Zimmermann, Zantech, Inc.

### Webex Attendees

Adriana Brown, NASA HQ  
Aileen Yingst, NASA  
Aki Roberge, NASA

Alfred McEwen, University Of Arizona  
Amy Chabot, Stellar Solutions  
Andrea Riley, NASA HQ  
Ashlee Wilkins, Science Committee  
Ashton Lum, Lewis-Burke Associates  
Ben Kallen, Lewis-Burke Associate  
Bo Trieu, NASA  
Bonnie Buratti, JPL  
Brad Bailey, NASA  
Brett Denevi, Johns Hopkins Applied Physics Lab  
Carol Freebs, Northrop Grumman Corporation  
Carolyn Ernst  
Casey Dryer  
Charles Acton, JPL  
Darby Dyar, NASA  
David Dunham  
David Eisenman, NASA JPL  
Delia Santiago-Materese, NASA Ames Research Center  
Emily Lakdawalla, The Planetary Society  
Emily Rathbone  
Gene Mikulka, Talking Space  
George Tahu, NASA HQ  
Grace Hu, Office Of Management and Budget  
Heidi Hammel, Aura  
James “Gerbs” Bauer, University Of Maryland  
James Lochner, USRA  
James Spry, SETI  
Jani Radebaugh MAPSIT  
Jeff Grossman, NASA HQ  
Jeff Moore, NASA  
Jeff Plaut, JPL  
John Rummel, SETI Institute  
Julie Rockland, TSI  
Kenneth Chang, NY Times  
Kurt Rutherford, SWRI  
Larry Nittler, Carnegie Institution  
Lilly Larsen, Arrow Space  
Marcia Smith, Space Policy on Line.com  
Matt Chojnacki, University of AZ  
Matthew Ticareno, SETI Institute  
Melissa Morris, NASA  
Michael Mean, Individual  
Michael Neil, Wave Haver Foundation  
Mike Kelly, NASA  
Mike Skrutskie, University of VA  
Monty DiBiasi, DiBiasi Assoc  
Megan Thompson, NASA HQ  
Noam Izenberg, JHUAPL  
Nola Redd, Freelance  
Paul Voosen  
Ramon DePaula, NASA

Richard Fischer, NASA  
Richard Rogers, Stellar Solutions  
Richard Zurek, NASA JPL  
Samuel Lawrence  
Sarah Sonnett, PSI  
Shoshana Weeda, NASA  
Sean McCarville, NASA  
Steven Hauck  
Thomas Thompson  
Tony Reichardt  
Trishana Leta  
Serina Diniega, JPL  
Stephen Clark, Space Flight Now  
Tim Lyons, University Of California  
Timothy McInahan, NASA  
Veronica McGregor, Jet Propulsion Laboratory  
William Knopf, NASA HQ

**Appendix B**  
**Planetary Science Advisory Committee Meeting**  
**Membership**

Anne Verbiscer, Chair  
University of Virginia

Robin Mihran Canup  
Southwest Research Institute

Lynn Marie Carter  
University of Arizona

Justin Filiberto  
Lunar and Planetary Institute

Chris German  
Woods Hole Oceanographic Institution

Justin Hagerty  
United States Geological Survey

Dana Hurley  
Johns Hopkins Applied Physics Laboratory

Timothy Lyons  
University of California – Riverside

Amanda K. Mainzer  
University of Arizona

Francis McCubbin  
NASA Johnson Space Center

Aki Roberge  
NASA Goddard Space Flight Center

Britney Schmidt  
Georgia Institute of Technology

Rhonda Stroud  
US Naval Research Laboratory

Stephen A. Rinehart  
Executive Secretary, NASA Headquarters

## Appendix C Agenda

March 09-10, 2020  
VIRTUAL

**\*Virtual Meeting Only\* The March 9-10 Planetary Science Advisory Committee (PAC) Spring meeting now will be held as a virtual meeting only, due to the coronavirus. There will be no in-person meeting at NASA Headquarters.**

### Monday, March 9, 2020, 10:30 a.m. – 5:30 p.m.

|       |   |               |
|-------|---|---------------|
| 10:30 | Opening, Announcements, Around the Table Identification | (S. Rinehart) |
| 10:35 | PSD Status Report                                       | (L. Glaze)    |
| 11:30 | PSD R&A Status  | (S. Rinehart) |

### 12:00 Working Lunch (Training)

|      |                      |                        |
|------|----------------------|------------------------|
| 1:00 | Planetary Protection | (R. McCauley Rench)    |
| 2:00 | Mars Program         | (M. Meyer & J. Watzin) |
| 2:30 | Lunar Program        | (S. Clarke)            |

### 3:00 Break

|      |                                       |                             |
|------|---------------------------------------|-----------------------------|
| 3:15 | Planetary Defense Coordination Office | (L. Johnson)                |
| 3:45 | PDS                                   | (L. Prockter/T. McClanahan) |
| 4:15 | PDS HQ                                | (R. McCauley Rench)         |
| 4:30 | Findings & Discussion                 |                             |

### 5:30 Adjourn

### Tuesday, March 10, 2020, 10:30 a.m. – 5:30 p.m.

|       |   |               |
|-------|---|---------------|
| 10:30 | Exoplanets in our Backyard                        | (N. Izenberg) |
| 10:50 | Astrophysics Assets for Solar System Observations | (J. Bauer)    |
| 11:15 | JWST  | (H. Hammel)   |
| 11:40 | Mercury Group                                     | (C. Ernst)    |

### 12:00 Lunch

|      |       |              |
|------|-------|--------------|
| 1:00 | VEXAG | (D. Dyar)    |
| 1:20 | SBAG  | (B. Buratti) |
| 1:40 | OPAG  | (J. Moore)   |
| 2:00 | MEPAG | (A. Yingst)  |

|      |        |                |
|------|--------|----------------|
| 2:20 | MAPSIT | (J. Radebaugh) |
| 2:40 | LEAG   | (S. Lawrence)  |
| 3:00 | CAPTEM | (K. McKeegan)  |

**3:20 Break**

3:30 Findings and Recommendations Discussions

**5:30 Adjourn**

## Appendix D Presentations

1. Planetary Science Division Status; *Lori Glaze*
2. PSD Research and Analysis Status; *Stephen Rinehart*
3. Planetary Protection; *Rebecca McCauley Rench*
4. Mars Exploration Program Update; *James Watzin*
5. Lunar Exploration Program; *Steve Clarke*
6. Planetary Data System; *Tim McClanahan*
7. PDS at Headquarters; *Rebecca McCauley Rench*
8. Exoplanets in Our Backyard; *Noam Izenberg*
9. Astrophysics Assets for Solar Systems Observations; *James “Gerbs” Bauer*
10. Solar System Science with JWST; *Heidi Hammel*
11. Mercury Group; *Carolyn Ernst*
12. VEXAG Report; *Darby Dyar*
13. SBAG Report; *Bonnie Buratti*
14. OPAG Report; *Jeffrey Moore*
15. MEPAG Report; *Aileen Yingst*
16. MAPSIT; *Jani Radebaugh*
17. LEAG Report; *Samuel Lawrence*
18. CAPTEM Report; *Kevin McKeegan*