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MEETING REPORT

Anne Verbiscer, Chair

Stephen Rinehart, Executive Secretary

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***Prepared by Joan M. Zimmermann
Zantech, Inc.***

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Opening and Announcements, Introductions

Ms. Doris Daou, Program Scientist at the Planetary Science Division (PSD) opened the meeting. Dr. Anne Verbiscer, Chair of the Planetary Science Advisory Committee (PAC), offered brief remarks, and introductions were made around the table. Dr. Lori Glaze, Director of the PSD, noted the challenging nature of the efforts to re-charter the PAC in 2019, and was pleased to be able to offer some important updates, particularly the results of the most recent Planetary Senior Review. Ms. Daou made some administrative comments.

SMD Welcome And Updates

Dr. Thomas Zurbuchen, Associate Administrator for the Science Mission Directorate (SMD), presented a status of the SMD. He noted that the PAC was the first committee chartered after recent changes in Federal Advisory Committee Act (FACA) rules.

Dr. Zurbuchen addressed the recently elevated status of Planetary Defense at NASA, remarking that the subject lay at the intersection of science with societal value, particularly in terms of safety and benefit to humans. Planetary Defense (PD) has received a \$150M budgetary appropriation, via Congressional directive, within SMD. The challenge at present is that PD is not a major topic in any of the more recent Decadal Surveys, which exert a large influence on determining the path forward for SMD. In the future, PD should be part of the Decadal Surveys. **Of recent note, two medium-sized asteroids flew within 14 lunar distances of the Earth in mid-September of this year, prompting a widely distributed press release by NASA, and drawing increased attention to the presence of NEOs and their potential hazards.**

The NASA Planetary Defense Strategy and Goals document states that the NASA will detect near-Earth Objects (NEOs), determine their orbits and physical characteristics using all data sources, and develop new technologies for detection and impact mitigation. In doing so, NASA will enable research in small bodies to study how the Solar System formed, and to determine hazards to life on Earth. The science is an important part of this effort, but it is not an explicit driver. The science is required to inform operations, and its key objectives are the detection of existing NEOs, improvement of detection, and mitigation of potential NEO hazards.

To implement the strategy, SMD will centralize the NEO search using dedicated ground-based (GB) assets, and will leverage astronomical assets, such as the mission-in-development, the Wide Field Infrared Survey Telescope (WFIRST), if needed, to observe NEOs post-discovery. Small- and medium-sized missions will also be focused on meeting NEO survey goals and developing technologies for impact mitigation; and there will be competitively selected NEO research projects that enable the analysis of breakthrough science.

PD missions will be approached like space weather or other operational programs; the output of these missions will provide key data for predictive algorithms, and other analytical tools for assessing NEO characteristics and potential hazards. Research will be competed to include only science activities that are needed for design, verification & validation, operations, and ground-based astronomical assets for meeting mission criteria. Development of the data will require scientific analysis.

Planetary Defense Projects

The NEO Wide-field Infrared Survey Explorer (NEOWISE) is a continuing mission in NEO survey operations, and is expected to exceed useful temperatures due to precession in Summer 2020. The Double Asteroid Redirection Test (DART) is a mission in development that will demonstrate the operation of a kinetic impactor to change the motion of an asteroid, and is targeting the moon of (65803) Didymos, a minor body in a binary asteroid system. DART is a Congressional priority, to be launched no earlier than July 2021. The mission's Critical Design Review (CDR) was completed in June 2019, and its Division

Program Management Council (DPMC) assessment was completed in August 2019. DART also carries a technology demonstration for a space propulsion system. DART is on schedule for launch on a SpaceX Falcon 9 launch vehicle.

A National Academies of Science Engineering and Medicine (NASEM) study was issued in June 2019, to evaluate the relative advantages of infrared (IR) and visible observations of NEOs. One of its key findings was that a dedicated, space-based mid-IR telescope designed to discover NEOs, particularly those under 140m in diameter, and operating in tandem with visible wavelength assets, would be necessary. The report recommended that such a telescope be developed within 10 years' time. The report also recommended that missions meeting high-priority PD objectives should not be required to compete against missions for high-priority science objectives. The telescope, if developed, should operate in conjunction with short- and long-term ground-based (GB) observations to determine orbits and physical properties of NEOs, to determine their potential threat to Earth.

IR survey capabilities have been proposed several times to Discovery Program Announcements of Opportunity (AOs). A proposal submitted to the 2014 Discovery Program AO, called NEOCam (Near-Earth Object Camera), did well but was not selected for flight. Dr. Zurbuchen said he did not select the proposal because it had not been sufficiently centered on science. An extended phase A proposal for NEOCam was approved, however, and supported maturation of the IR instrument. Dr. Zurbuchen said he had not appreciated the various voices that were in support of NEOCam at the time, and that this experience constituted an important Lesson Learned. The phase A efforts of NEOCam, combined with the recent Congressional provision for PD, has provided new momentum and alignment to properly initiate a new NEO Surveillance Mission (NEOSM), consistent with the NASA PD strategy, to be costed in the \$500-600M range, including options for a shared or dedicated launch vehicle, and with separate funds for research and analysis (R&A). The mission will be designed to meet the criteria of the 2005 George E. Brown Act.

The objectives of this directed mission will be to find 65% of undiscovered potentially hazardous asteroids (PHAs), down to 140m in diameter, within 5 years, and 90% of them in 10 years. Sizes will be determined from IR signatures, and albedos will be computed when visible data are available. These data will be used to compute the cumulative chance of impact over the next century for PHAs. The mission will carry a wide-field IR (4-10 micron) instrument based on high-temperature HgCdTe detectors (new technology), and will employ a heritage-based spacecraft with the approximate wet mass of one metric ton. Other mission parameters are a fixed survey pattern, 12-year lifetime, a Sun-Earth L1 halo orbit, the use of the NASA Infrared Processing and Analysis Center (IPAC) for data processing and analysis, passive cooling, and an average power for operations of less than 60W. The instrument design is mature and ready for phase B. The NEO Surveillance Mission's instrument-first project review was completed in March 2019, and has been assigned a launch readiness date of no earlier than 2025. Dr. Zurbuchen expected that the scientists involved with NEOCam will be fully involved in NEOSM, the new surveillance mission, which will be developed between PSD and the Planetary Defense Coordination Office (PDCO).

Dr. Aki Roberge asked about the use of NEOCam technology in the new surveillance mission. Dr. Zurbuchen said that he felt that the instrument had matured during its phase A development, and that a from-scratch procurement effort was not worthwhile, thus in the running for use. He added that the surveillance mission is now being directed to the Jet Propulsion Laboratory (JPL). Dr. Glaze noted that this mission is a big step, and is something PSD has wanted to do for quite a while; she said that Dr. Zurbuchen had presented the details of the pieces that have been developed over the last few years, which now constitute an effort that can go forward as a directed mission. Dr. Verbiscer reminded the PAC that the mission falls under a new budget line, and has no relation to the Discovery Program, which has an ongoing budget line; the new surveillance mission does not affect Discovery science missions in any way.

Dr. Zurbuchen concurred with this assessment, adding that the mission actually adds to the portfolio of PSD. The PD Line is now in the PSD budget for the current Fiscal Year 2019 (FY19). The mission will require the attention of the entire science community and relevant stakeholders, and really needs to be addressed in the upcoming Planetary Decadal Survey. Dr. Glaze said that she was working on a statement of task to the Decadal Survey. Dr. Britney Schmidt asked if all the NEOCam phase A activity had been developed under a Principal Investigator (PI), and what the role of the NEOCam PI was to be in future planning. Dr. Zurbuchen said he expected NEOCam's PI to play a crucial role, but could not discuss details just yet. PAC member Dr. Amanda Mainzer, the NEOCam PI in question, said she had just changed institutions. Dr. Zurbuchen commented that Dr. Mainzer's new location (University of Arizona) would provide new opportunities and broader benefits to the entire program. Dr. Roberge asked about the nature of the PD budget line. Dr. Zurbuchen likened it to a Discovery budget line, but with GB and research programs associated with it; he added that the next budget increase after DART would be targeted to NEOSM. Dr. Glaze noted that FY19 contains \$150M for PD, including GB observing and research, the line for DART, and continuing operations of NEOWISE. Dr. Verbiscer asked if there would be a competition for science team membership. Dr. Zurbuchen noted that there is already a science team in place for the mission; in the future, there can be a competition for a visiting scientist program, through PDCO. Dr. Zurbuchen reiterated that PSD should think about creating a work force for applied planetary science. Dr. Mainzer thanked Dr. Zurbuchen for helping to clarify the mission, adding that such missions generate rich data sets for science and purely curiosity-driven research. A representative online from BuzzFeed asked if the current budget allocation would be enough to support this new PD line. Dr. Zurbuchen commented that the FY2020 budget is currently under discussion, but that there would be no new announcement until February 2020; how NASA goes forward is still to be determined.

PSD Status Report

Dr. Lori Glaze, Director of the Planetary Science Division (PSD), presented a status of the Division. She remarked on the "lens" through which PSD carries out its science objectives— innovation, inspiration, and interconnectivity. The newly created Small Innovative Missions for Planetary Exploration (SIMPLEx) mission line exemplifies how PSD is pushing the boundaries of innovation, while also thinking about other disciplines; all four science divisions are working together in the disciplines of exobiology and astrobiology, while providing inspiration to the next generation of scientists and engineers, the future work force.

The Planetary fleet now comprises 24 missions: 13 in operation, and 11 in development, including collaborations with international space agencies. Dragonfly is the most recent selection in the New Frontiers program. The Mars Exploration Program is getting quite busy, thinking ahead to the Mars 2020 rover that will launch in July 2020. The European Space Agency (ESA) ExoMars rover will also launch in the same month. The Japanese space agency's (JAXA's) Martian Moons eXploration (MMX) mission to Phobos and Deimos is in development for launch in the early 2020s. PSD is also focused on the Artemis lunar program, in which PSD will play the role of producing the enabling science for Moon and Mars exploration. PSD also oversees the Lunar Reconnaissance Orbiter (LRO) and the commercial lunar payload services (CLPS), and is also involved in an internal NASA effort for developing a lunar rover.

The Dragonfly mission has been selected in the New Frontiers Program to probe Titan for origins and signs of life; the mission will include an octocopter drone that will land on Titan's surface, fly multiple sorties, and characterize the organics-rich environment that is believed to be similar to early, pre-biotic Earth. Its launch date is no earlier than 2026.

The Europa Clipper mission is now confirmed, and is one of the highest ranked missions in the 2013 Planetary Decadal Survey; The mission seeks to understand the geology of Europa's surface, and is working hard to keep costs and scope within bounds. Data from the Juno mission indicate that Jupiter has a time-variable magnetic field, suggesting that there are many interesting characteristics of the Jovian

interior structure still to be discovered. The Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) spacecraft arrived at the asteroid (101955) Bennu in December 2018, and is still trying to identify a sampling site. Four candidate sites were identified in August 2019, but many large boulders on the surface of the entire asteroid have made operations difficult. The mission team is working on optical navigation tools to help refine the site selection task. DART is moving forward, as previously described.

The Mars Science Laboratory (MSL) Curiosity rover has reached the “clay unit” that had been identified by orbital assets. Drilling, sampling, and wet chemistry assays of this unit are now complete; data are in the process of being relayed back to Earth. The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission has detected numerous seismic events on Mars. As of 30 July, at least two “Marsquakes” of magnitude 3.5 to 4 have been detected, along with localized source data; analysis is currently in progress. Mars 2020 remains on schedule, and all is going well. This past summer, all instruments were delivered and integrated onto the Mars 2020 (M2020) rover. The rover has been stacked onto the descent system and is undergoing environmental testing. M2020’s landing site, Jezero Crater, is a compelling site for sample collection and surface study. The crater is estimated to be 3.5 billion years old, and includes a river delta. Mars Sample Return (MSR) Sample planning has now begun in earnest, fueled in part by a Planetary Decadal Survey midterm review recommendation to bring samples back as soon as possible. NASA has been working with ESA on a notional sample return architecture; NASA funding for MSR is now in the proposed FY2020 federal budget under development. The notional architecture includes three launches from Earth and one from Mars. A NASA-developed lander would carry an ESA-developed fetch rover to the surface; if M2020 is still healthy, it could bring some samples to lander and the Mars Ascent Vehicle (MAV). An ESA-provided Earth-return orbiter would carry sample return capsules back to Earth. NASA and ESA have signed a joint statement of intent to jointly develop MSR plans by the end of 2019, and to be prepared to make an informed decision by Spring 2020.

Dr. Glaze detailed some PSD personnel changes. Dr. Jonathan Rall has moved to the Associate Chief Scientist for Programs and Project position in the NASA Office of the Chief Scientist (OCS). Dr. Stephen Rinehart has stepped in on a 6-month detail to lead the R&A program in Dr. Rall’s place. NASA will soon advertise for the R&A lead position. Dr. Glaze thanked Dr. Kate Wolf in her acting capacity as Deputy Division Director (DDD). Dr. Eric Ianson has been confirmed as the new DDD and will join PSD on 30 September. Dr. Ianson has extensive experience with the Earth Science Division (ESD) Flight program. Dr. Joan Salute will start her position as Associate Director for the Planetary Flight program.

The Exoplanet Research Program (XRP) now includes the Heliophysics and Earth Science Divisions (HPD and ESD) in addition to the Astrophysics Division (APD) and PSD; all reviews will be managed collaboratively by all four divisions, selections will be funding-blind. XRP has observed a 20 percent increase in proposals compared to the previous year. ROSES20 will include a consolidation of exoplanet proposals into XRP; panels will need Heliophysics and Earth Science expertise to review these proposals. PSD hopes to encourage further cross-divisional collaboration in XRP, and hopes to simplify and streamline the approach to create an unambiguous, “one-stop shop” for exoplanet research.

Dr. Glaze reported that the astrobiology research discipline has grown a strong community over the last 20 years. As a result, NASA has decided to sunset the NASA Astrobiology Institute (NAI), and in its place, is establishing a new solicitation for larger, longer-duration grants that will be released in October 2019, in discipline areas such as prebiotic chemistry and early Earth environments,

Recent Announcements of Opportunity (AOs) include one in the SIMPLEx line, a new small satellite science program with a mission cap of \$55M. Three missions have been selected to go forward in phase A/B studies. They are: Janus Reconnaissance Missions to Binary Asteroids (which has overlap with PD),

Escape and Plasma Acceleration and Dynamics Explorers (EscaPADE) to Mars (to measure atmospheric loss), and Lunar Trailblazer (a water mapper, with a next-generation hyperspectral imager). The New Frontiers #4 call has resulted in the selection of the Dragonfly mission to the Saturnian moon, Titan. For Discovery 2019, step-1 selections are now scheduled for January 2020, and step-2 selections are planned for no earlier than April 2021. Dr. Tom Wagner has been named as Lead Program Scientist for Discovery, replacing Dr. Michael New.

PSD has instituted some projects that are dedicated to inspiring future leaders. An initiative entitled Mission Principal Investigator (PI) Development was created in 2018, focused on early-career scientists, and received much feedback. NASA responded by developing a consolidated PI resource webpage. NASA also now has a code of conduct requirement for its conferences, and has re-started proposal writing workshops. The Discovery Program now requires a deputy PI in its proposals to allow for mentoring opportunities. Dr. Zurbuchen led a well-received, live-streamed colloquium in June entitled *Writing Successful Mission Proposals*. Dr. Mainzer noted that that NASA could also help elevate the focus on the rest of the mission team as well. Dr. Glaze said that PSD is still working on how to develop evaluation criteria for diverse and inclusive teams, and has seen progress in this area in both the New Frontiers and Discovery Programs. Dr. Mainzer reported that there is still an underrepresentation in the technical teams (particularly for instruments). Dr. Glaze acknowledged this issue. PSD is also preparing for the next Decadal Survey; the kickoff will take place in Summer 2020. The plan is to initiate the 2023 Decadal Survey, with the final report to be delivered in Spring 2022 at the Lunar and Planetary Science Conference (LPSC) in Houston. PSD is putting together series of webinars to inform early career scientists about the Decadal Survey process. With respect to white papers, NASA is recommending that contributors streamline their submissions, with multiple authors on one paper. The Lunar and Planetary Institute (LPI) website will host a main page on the Decadal Survey, to help connect people. Each of the discipline Assessment and Analysis Groups (AGs) are doing similar things. NASA is also working with the National Science Foundation (NSF), and has invited the AGs to provide thoughts on the organization of this joint effort. NASA also met with the NASEM Committee on Astrobiology and Planetary Science (CAPS) in September.

PSD R&A Status

Dr. Stephen Rinehart, Executive Secretary for the PSD, and Acting Director of R&A, began his presentation by recounting his background in the Astrophysics Division, involvement with planetary instrumentation, and his lead activities for both the XRP and the Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) programs. He provided a general update of the program. Due to the government shutdown, the ROSES 2019 call was not released until March 2019, and a National Academies study on investments in instruments and facilities was also released. R&A restructuring continues, and may include a facilities call. There is now an R&A policy in place on archiving manuscripts. There were some impacts to R&A due to the government shutdown at the beginning of the year: ROSES19 slipped by a month, and proposal due dates for Habitable Worlds (HW) and Solar System Workings (SSW) were delayed by two months. Review panels for five programs were also delayed, as was a Solar System Exploration Research Virtual Institute (SSERVI) panel. The backlog in the NASA Shared Services Center (NSSC) has delayed grants for up to four months.

ROSES18 was also heavily impacted by the shutdown in terms of days from step-2 to selection. Dr. Mainzer commented on the high variability in the ROSES18 selection rate. Dr. Rinehart agreed that the huge disparity needs to be discussed, but that part of the issue was due to very small numbers of proposals in some programs, and very large numbers of proposals in programs such as Exobiology. He conceded that a re-balance was necessary and that the task was on his to-do list. ROSES20 will contain some minor changes: what's out is the Apollo Next Generation Sample Analysis (ANGSA, selections are now complete), and LunaTech (which never got started). The Korea Pathfinder Lunar Orbiter (KPLO) has been delayed due to problems on the South Korean side. What's new is the DART Participating Scientist

Program (PSP), as well as a potential facilities call, the latter of which is under discussion. Changes to XRP include the adoption of cross-divisional, joint reviews and selections. ICAR, the Interdisciplinary Consortia for Astrobiology Research, and replacement for NAI, is now in place. Future Investigators in NASA Earth and Space Science and Technology (FINESST) experienced a significant increase in proposal submissions over the past years: 300 were submitted in March 2019. Overall budgets have not changed, but this will not impact the newly created NASA Earth and Space Science Fellowship (NESSF) graduate award program. NESSF is not a fellowship; it is a grant like any other grant, with a limited cost category award, in that no overhead costs are covered. There will also be new Early Career Awards, approximately five one-time awards per year of up to \$200K. To be eligible, the awardee will need to have an eligible ROSES award from a participating element; a PhD within last 10 years; an affiliation with an institution. An awardee cannot be a previous recipient of an ECF. The competitive Early Career award is emphasizing the non-research components: leadership, and working with students. It will have a separate panel.

The ROSES17 saw an overall selection rate of 22% (selected/submitted); this includes all core programs, such as the Data Analysis programs. Almost every proposal that was rated Excellent was funded. Those rated Fair to Good were selected at a rate of 2%. The speed of money getting to awardees is improving, but PSD can still do better. Dr. Rinehart said he had still not entirely determined the impact of the shutdown. He noted great difficulty in getting PSD R&A reviewers to serve on panels; in order to get 165 reviewers in SSW, for example in 2017, PSD needed to query 500. Dr. Rinehart strongly encouraged committee members to join the effort in identifying more panelists. Dr. Robin Canup asked: are you having an easier time after the Internal Scientist Funding Model (ISFM) exercise? Dr. Glaze and Dr. New noted that ISFM metrics are still being analyzed in preparation for an interim review of ISFM, in December. Some data have been collected, and results depend largely on the division. PSD, for one, has seen an uptick in Civil Servant reviewers. Dr. Rinehart added that he had seen a slight increase in XRP reviewers, and felt that getting the real statistics will help future efforts. Dr. Canup said she had been stunned by the difficulty in filling panels, and that the process felt almost prohibitive. Dr. Rinehart noted that the shutdown had also greatly affected the panels. Dr. Schmidt asked if there had been any attempt to see who has been on a panel before actually requesting that they serve; this would help. Dr. Rinehart replied that there was no global coordination, however there is the MARIE proposal review system, but he was not sure everyone uses it. The NASA NSPIRES database tracks external reviewers only.

Dr. Roberge commented that something must be done to reduce the burden on the community, such as the application of more vigorous triage, as is practiced in the Hubble Space Telescope (HST) Guest Observer (GO) program. Dr. Rinehart agreed that the situation needed addressing, across all of SMD. Dr. Canup said the situation was much worse than she had witnessed during the previous 10-20 years; she felt that program managers (PMs) were taking excessive time to find these reviewers. Dr. Glaze noted that both APD and PSD studies had concluded that when selection rates go below 30%, a negative feedback loop comes into play. Conflict of interest (COI) issues have also become much more stark in interpretation. Henry Throop confirmed the general sense that trying to find highly qualified reviewers in large programs tends to intersect heavily with COI issues. Dr. Roberge said she felt that Headquarters seemed resistant to adopting successful HST strategies. Dr. Hurley commented that if one gets proposal feedback sooner, it can help reduce the number of proposals.

Lunar Discovery and Exploration Program (LDEP)

Mr. Steve Clarke, Deputy Associate Administrator for the Lunar Discovery and Exploration Program (LDEP), the locus for Exploration in SMD, which was initiated at the beginning of the current fiscal year. He introduced Dr. Brad Bailey, the new Program Scientist for LDEP, and a former SSERVI Deputy Director.

Dr. Bailey presented a status of Lunar Discovery and Exploration Program: CLPS, Early South Pole Crater Rim Missions, VIPER, Volatiles Investigating Polar Exploration Rover, Instrument Development and Delivery (maturation of instrument concepts = DALI), Long Duration Rover Investments, LRO Mission Ops, Lunar Small Sats, and ANGSA.

There are nine current awards for Commercial Lunar Payload Services (CLPS); these services are acquired through task orders. The First Lunar Surface Transportation Task Order was awarded May 2019. LDEP anticipates two task orders per year, usually one polar and one mid-latitude lunar target. Astrobotic of Pittsburgh was awarded \$79.5M to fly as many as 14 payloads to Lacus Mortis by July 2021. Intuitive Machines was awarded \$77M to fly payloads to various lunar locations. LDEP will have an on-ramp for larger payloads (up to 400 kg); a Source Selection meeting for this effort will take place in October 2019. Instruments that will fly on CLPS were selected via an internal NASA call that resulted in a selection of 13 instruments. LDEP plans to have future calls on an annual basis, including calls for PI-led instrument suites. The 13 selections are a mix of science, operations and technology demonstrations. An external call resulted in an additional 12 payloads that were selected in July 2019. The Lunar Mobility Strategy for science purposes will include investigations for ground truth for volatiles on the lunar surface, and how to increase duration of operations. In parallel, LDEP will have an in-house development effort for the VIPER lunar rover. VIPER is an intersection between science and exploration; it will explore the spatial distribution of volatiles; its reservoirs, sinks and history. Mission features include multi-lunar day duration at the lunar South Pole, launch in late 2022, and the ability to traverse tens of kilometers. The payload contains a neutron spectrometer system (NSS), developed at Ames Research Center; NIRVSS (near infrared volatiles spectrometer system) mineralogy; Mass Spectrometer Observing Lunar Operations (MSolo; Kennedy Space Center); and The Regolith and Ice Drill for Exploring New Terrain (TRIDENT; Honeybee Robotic).

Under the SIMPLEx program, LDEP will include the Lunar Trailblazer, an ESPA-ring-sized small satellite, which will fly two instruments: HVM3 and Lunar Thermal Mapper. The ANGSA project included nine teams that were selected to analyze untouched Apollo samples, (Apollo 15 and 17), using techniques that were not available in the 1970s, including x-ray tomography. The Lunar Reconnaissance Orbiter (LRO) has just marked a decade of operations, and has provided data on new impact craters, and bombardment rates. LRO is reasonably healthy. There is a small issue with the battery, but LRO is still expected to be in operation for several more years. LDEP is currently working on a science strategy for the Moon, including an implementation strategy that will be PI-driven. Science that will need to be accomplished by 2024 will require the use of polar and non-polar landers and rovers to investigate lunar magnetic swirls, young volcanic areas, and far-side radio-silent regions, and will also require orbital data (in the form of cubesats for orbital mineral mapping; and communications and data relay).

LDEP is planning an early 2020 workshop on implementation strategy and crew planning, to develop an exploration science mission plan for the first human return mission to the lunar surface. Dr. Roberge asked: where is the science strategy for the Gateway? Dr. Bailey said that LDEP has been discussing approaches to science strategy with the Human Exploration and Operations Mission Directorate (HEOMD), which has identified several different science issues, including radiation internal and external to Gateway. It is expected that there will be two to three monitoring experiments on the enhanced Gateway configuration (second payload delivery). Mr. Clarke reported that there was a Deep Space Gateway Concept Science Workshop in Denver in December 2018 (based on original 2028 plans), from which NASA received good input. While NASA is looking at a minimal Gateway for a 2024 landing, phase 2 of the Gateway will provide additional science opportunities. The National Academies will be studying science opportunities for beyond 2024, which LDEP hopes to kick off in early to mid-2020. Dr. Glaze added that LDEP and Gateway are completely open to other science disciplines, and technology development projects. Mr. Clarke noted that technology development is still a large component of the

LDEP effort, via ties to the Space Technology Mission Directorate (STMD). There are also ongoing discussions with HEOMD about mounting instruments on the Power Propulsion Element (PPE), a major component of the Gateway infrastructure.

Ethics Briefing

The PAC received its annual ethics briefing.

PSD Senior Review Subcommittee

Mr. Bill Knopf, lead Program Executive for Mission Operations in PSD, introduced the presentation, noting that this most recent PSD Senior Review had been the first to have been subjected to the Federal Advisory Committee Act (FACA) process. Dr. Ralph McNutt, subcommittee chair for the Review, provided the results of the May 2019 PSD Senior Review Subcommittee (SRS) report. Dr. McNutt reviewed the approaches to the creation of the report, and noted that there had been concerns about lack of appropriate expertise to address the technical merit of some of the missions, due to COI and difficulty in identifying subject matter experts (SMEs) for certain panels. That said, Dr. McNutt said he was confident that the review was thorough and appropriate, and that end result was a consensus document, without minority reports. Briefly, LRO, the Mars Reconnaissance Orbiter (MRO), MSL, Mars Odyssey (MODY) all received Excellent ratings, and the Mars Atmosphere and Volatile Evolution (MAVEN) mission received a Very Good/Excellent rating. Mars Express (MEX) received the lowest grade of Good to Very Good, and was judged to be limited in its science value.

Dr. McNutt went on to highlight particular findings:

LRO— SRS found that the new NASA policies regarding lunar exploration, which emerged after the LRO proposal was submitted, limited the ability of the project to discern implications of the new budget policy on LRO requirements. As a result, the SRS concluded that LRO's requested in-guide funding is appropriate, with considerations for the future.

MAVEN—The SRS recommended that MAVEN receive in-guide funding.

Mars Express— The SRS agreed with the SME panel that insufficient justification for science was given. SRS worried about productivity, and was concerned that the Planetary Data System (PDS) was not being used widely by the community. If support is continued for MEX, SRS believes it should be at a descope level, and that it is currently incorrectly categorized as a NASA science mission. Dr. Mainzer asked if MEX should be regarded as more of an operational mission. Dr. McNutt said that the proposal simply didn't contain a strong science case. However, there may be policy and programmatic reasons to keep it going.

MODY— SRS commended MODY for the high science productivity of the team, but expressed concern that the budget was insufficient, and therefore recommended the requested overguide for science operations. SRS also recommended that cost risk analysis be determined to determine whether an STL upgrade was necessary.

MRO— SRS recommended funding items one and two out of three requested, and felt that the proposed unallocated future expenses (UFE) was high and could be applied to a portion of the overguide.

MSL—The SRS issued several findings on the reduction of radioisotopic power, recommended funding an overguide to add command cycles, and added that the MSL team should focus more on sampling and analysis rather than extending drive distance. The SRS also found that the UFE was inappropriately high.

Mission rankings, based on the NASA Planetary Science Division (Consolidated) Senior Review Findings 2019 form, with numerical scores based on the legend: 5=Excellent to 1=Poor.

- LRO- Science 4.8, technical 5.0; no science or technical weaknesses were identified. In the report, there are several science and technical strengths enumerated.
- MAVEN- Sci 4.57, Technical 4.43, no science or technical weaknesses were identified.
- MEX Sci 1.50. Limited Science (Descope) 3.60 (Good/Very Good). Technical 3.00. Both science and technical weaknesses were identified and enumerated. The general consensus was that funding for MEX is 90% operational, 10% science (via comments by Doug McCuistion).
- MODY- Science: Inguide funding 2.75, overguide 4.75. No major science weaknesses. Technical: inguide 2.75, overguide 4.75. SRS had some concerns about gyro and antenna failures, and the amount of funding for co-investigators.
- MRO- Science 4.75, Technical 5.0
- MSL Science 5.0, Technical 4.5

The PAC discussed SRS findings on implementation strategy. Dr. Mainzer commented that the Earth Science Division (ESD) has an applications panel, and wondered if such a panel might be useful in a Senior Review, to enable consideration of Mars Express as a telecommunications relay asset. Dr. McNutt said the subcommittee had talked about this, but felt some of the issues were largely unique to the Mars program. Some members did feel that an applications focus would help in future SRs. In discussing suggestions for improvement, Dr. McNutt said the SRS felt that content could be structured more succinctly, and that teams should provide pertinent data to back up claims; e.g., if a mission claims that everyone is using its data, then the mission should provide a list of publications to support the assertion. Overall, SRS saw a need to streamline content, to avoid overwriting, and to focus on answering the pertinent questions. Many missions did not follow the guidelines they were given and spent far too much time on proposals. A Mars scientist in attendance suggested that some more detailed questions might be helpful to the PIs.

Dr. McNutt commented that different SMEs handled different options differently, implying that panels should be given more explicit instruction in the future. Dr. Timothy Lyons said he was impressed by how rigorously the Senior Review was carried out, and as an SME participant, he thought the report would be very useful to the PAC. Mars Express would be the toughest call. He also praised the document for including the SME writing opinions.

Dr. Amitabha Ghosh, an SME on the SRS, commented that there was agreement amongst NASA participants for all missions except for MSL, where there was some difference among SME panels. Mr. McCuistion noted that MSL really needed the overguide to focus on sampling, and that was the essential difference of opinion; the majority voted for the inguide option. Mr. McCuistion said the SMEs had asked the right questions, but the fact that the radioisotopic power is decreasing means that it really affects what the rover can do, combined with the problem of memory/battery storage. If the range of detectable organic molecules were able to be expanded, there might have been a different outcome (M2020 will not have a mass spectrometer).

Agenda change

The agenda was altered to include a discussion of Senior Review results on the morning of 24 September.

Mars Exploration Program (MEP)

Dr. James Watzin presented an update on the Mars Exploration Program (MEP). All operating missions are doing well; MRO, ODY, MSL and MAVEN have just come out of conjunction and are communicating again. The MAVEN orbit adjustment has been completed. The ESA Trace Gas Orbiter (TGO) is still providing relay support for NASA surface missions, and the MER Opportunity rover has been lost to a dust storm.

NASA's Mars Organic Molecule Analyzer (MOMA) instrument has been integrated into the ESA ExoMars rover, and its functional testing is complete. The Mars 2020 rover is now in its environmental test phase, and remains on schedule for a July 2020 launch. Planning for MSR with ESA is progressing well; a successful Agency Acquisition Strategy Meeting was completed on this subject, and staffing up has begun on pre-projects, and to support the Decadal Survey. The FY19 budget appropriation was overstressed due to M2020, but problems have stabilized, with M2020 back on track, and there is substantial margin to support the launch. The 2020 Presidential Budget Request (PBR) was favorable to the Mars program.

Mars 2020

Jezero Crater has been selected as the landing site, allowing the team to focus on planning execution and trajectories. An Entry, Descent and Landing (EDL) team is also finalizing planning. M2020 is part way through vibration testing at present. The Mars "helicopter" is integrated as well, and is being tested. M2020 has a new heat shield, after finding the root cause of a crack that formed during initial testing. The new shield is actually a spare from MSL days. The design had been updated for MSL, and had been revised to be more robust than the one that flew successfully with MSL. The rover's sample caching system is being tested, and is drilling and caching real rocks, at Mars pressure and atmosphere, at Mars thermal conditions. This is "dirty" testing, to thoroughly simulate Mars conditions. There is a healthy schedule reserve of 48 work days, at present; the first shipment to the Kennedy Space Center (KSC) will take place in three months.

MSR

Throughout 2018 and 2019, NASA and ESA have been converging on MSR campaign requirements, and considering a 2026 launch date to allow possible overlap with existing rovers on Mars. NASA and ESA signed a joint statement of intent at the Berlin Air Show and since that time, have been doing a number of joint studies. ESA has done extensive internal studies (four industry studies for an orbiter and fetch rover), which NASA is using as a guide for its own planning. In July 2019, ESA released an Invitation to Tender for an Earth Return Orbiter; they have been acting quite aggressively on schedule. The ESA ministerial council will meet at the end of November and consider the approval of MSR. For NASA, the 2019 appropriation and the 2020 PBR both support MSR. MSR will be an integrated campaign: sample caching rover in 2020, sample retrieval lander (with Mars Ascent Vehicle (MAV) and fetch rover), and Earth Return Orbiter (which carries out the rendezvous with cache). Currently planning has focused on flight elements, and has not yet addressed sample return facilities. NASA hopes to initiate these latter plans next year pending the approval of the overall campaign.

MSR Architecture elements

The ESA MSR investment is \$1.7B (USD), representing about 20% of the ESA human and robotic exploration portfolio. NASA's JPL, the campaign leader, will be responsible for M2020 and MSR operations and the container module. Marshall Space Flight Center (MSFC) is the lead on the Mars Ascent Vehicle (MAV); Langley Research Center is the lead on the Earth Entry Vehicle (EEV). Ames Research Center is the lead on the thermal protection system (TPS). Glenn Research Center is the lead for ESA's Sample Fetch Rover (SFR) tires. Goddard Space Flight Center (GSFC) is the lead for the Containment, Capture and Return System (CCRS) and the

transfer module; Kennedy Space Center (KSC), the launch vehicle; and Johnson Space Center (JSC), sample curation. MEP is a healthy and productive program, making good progress toward the first roundtrip to another planet. Dr. Mainzer asked: what will the instrumentation look like? Dr. Watzin said there would be no piggyback science on this mission, as it is considered an engineering campaign. Mars 2020 is being designed to hold sample collection tubes, and drive to a location to disperse for the fetch rover, or to just remain as a static cache, in case it is a long time before retrieval. The collection of samples could be dropped into one location, to be retrieved by the fetch rover at a later time. If M2020 is still operating, it could deliver samples to the lander as well, maximizing the probability of getting samples to the fetch rover and MAV. Dr. Francis McCubbin asked about NASA's investment in MSR. Dr. Watzin said this number could not be shared publicly, but it has been shared internally. Asked about any concerns about samples being damaged during ballistic entry, Dr. Watzin said that the engineers feel the samples will be well protected, while some on the science side would like more testing, which will probably go forward once a budget is established.

As to sample-sharing strategy, MSR is planning for equitable distribution of samples; all participants will have active involvement in governing how samples are distributed. NASA and ESA have agreed that the science investigations on the samples will be competitive and open to the entire international community. Mr. Michael Meyer and ESA are working on developing principles, and will be holding workshops on the subject. The idea of governance is also being treated. Dr. Lyons asked if ESA will play a role in sample site selection. Dr. Watzin noted that M2020 is a NASA mission, but there has been participation of international scientists in its development. Drilling sites are the responsibility of the 2020 science team, which will be open across the community, both US and international. Asked if there will be a memorandum of understanding (MOU) for sample sharing, Dr. Watzin felt there would probably be some new approaches, in addition to traditional MOUs, but the primary investors will probably have preferential access to the samples. Dr. New commented that NASA policy states that after a short period of preliminary access, samples are made freely available; anything contrary to the policy would be a new approach. Dr. McCubbin commented that exclusive access is typically restricted to 6 months. Dr. Watzin noted that the intent is to follow classical models as closely as possible.

Discussion

Dr. Roberge reported a Twitter rumor claiming that Decadal Survey white paper authors would be banned from participating in Decadal Survey deliberations. Dr. Glaze dismissed the rumor as untrue. Dr. Glaze went on to note that a debate is ongoing as to how the Decadal Survey would be focused: a targeted vs. science approach? Destination vs. big questions? A recent discussion on the subject at the September 2019 CAPS meeting went on for two days, with no consensus reached. Dr. Steve Squyres, Chair of the 2013 Planetary Decadal Survey, argued that either approach would work well. There is still some room in the task statement as to how PSD and the community wants the information to be delivered. There could presumably be a hybrid approach. Dr. Verbiscer said there had been some discussion about opening up the New Frontiers (NF) Program to any destination, which would result in a more science-focused approach. Dr. Glaze noted that the NF discussion converged on retaining specified destinations, for a variety of reasons. One argument was the load on NASA Centers, and how the strategic nature of NF would allow Centers to propose how the missions were structured. Ultimately, Dr. Glaze felt that Decadal Survey should serve as strategic guide to NASA. Dr. Schmidt asked: can you do a Flagship with a NF budget? Will the direction to the Decadal Survey include throwing off some previously listed priorities? Dr. Glaze said there had been some discussion of the former idea, again without resolution. As to the second question, Dr. Glaze thought that support for the latest science findings would drive priorities, opening up the possibility that some inherited targets could disappear. Dr. Hurley asked about New Frontiers 5. Dr. Glaze said she was asking the Academies to assess the NF #5 list during the Spring meeting. Dr. Canup asked about the inclusion of exoplanets in the Planetary Decadal Survey. Dr. Glaze said that clearly, Planetary plays a role in exoplanet science, based on how planets are used to inform the

interpretation of exoplanets. However, PSD must be careful not to trample on the purview of the Astrophysics Decadal Survey.

The PAC discussed the assessment of the ISFM, whether it has been effective and has had the desired impacts, and how its approaches were implemented. Dr. Glaze commented that there has already been an effort to make approaches more consistent. Dr. Roberge asked: what should be in and out of bounds for ISFM? Dr. Glaze said that the intent on the Planetary and Astrophysics sides were very different. At Planetary, the focus was on having Civil Servants giving back to the community. Another metric of success was a reduction overall number of proposals. Dr. Canup felt that exoplanets have been underfunded and would benefit from a big-question approach. Dr. Schmidt said that it might be worthwhile to look at the questions the Astrophysics panel is looking at in the search-for-life question. Dr. Lyons reported that this is happening at PSD through the Nexus for Exoplanet System Science (NExSS), and speculated that using NExSS might be a way to optimize partnerships. Dr. Glaze noted that the purpose of the CAPS meeting was to have the National Academies hear the various issues, and felt that there was a danger of being too proscriptive in the statement of task, and of creating circular arguments.

Dr. Lyons asked if any of the money freed up by the NAI dissolution was being used to fund research coordination networks (RCNs) in Astrophysics. Dr. Glaze said that some funding for life detection research had been folded into a work package. Dr. Roberge felt that the NAI summer schools had been worthwhile. Dr. Lyons thought the summer schools had been picked up and continued, but that the international partnerships seem to have fallen through the cracks. Dr. Roberge requested a list of the relevant RCNs and a review of how things are being handed off, as well as an enumeration of WFIRST Solar System science capabilities. Dr. Mainzer mentioned that there was a recently published paper that describes the various science cases for WFIRST, and that it is not considered an optimal tool for NEOs.

Dr. Mainzer asked: how do we ensure support for the research community, with these big missions coming down the pike, for tasks such as analyzing data and maximizing science return? Dr. Rinehart said that there is an active discussion in R&A on issues such as provision of processed data products, e.g. Dr. Mainzer commented that there is always a trade between the size and complexity of the spacecraft and the money available for data analysis. Dr. Hurley felt there was a risk of losing people in the field, who won't be around to process the data when the time comes. Dr. Schmidt commented that it was nearly impossible to predict what salary and tuition costs will be when Europa Clipper reaches its target, given the shrinking science budgets. Dr. New requested hearing more about Dr. Schmidt's concerns off-line, and wanted to know why these considerations were not built in to the original funding profile for the Europa Clipper. He added that it might be helpful to address the problem in the Planetary Decadal Survey. Dr. Hagerty commented that from the SSW perspective, so many people proposing to one program is putting undue pressure on selection rates. Dr. Glaze agreed that PSD needs to step back and look at selection rates across the division. Dr. Rinehart said that PSD can only work on the process by which people get money, in a way to get good science. He felt that R&A reviewers could randomly select from the top 30% of proposals and still get a great program. Asked to comment on international travel restrictions, Dr. Glaze clarified that these restrictions are written into law for Civil Servants, and will therefore remain. The issue for contractors, however, is being addressed. It would be beneficial to periodically remind NASA of the issue through a specific finding. Dr. Stroud asked for some clarification of the Interdisciplinary Consortia for Astrobiology Research (ICAR) status. Dr. Glaze noted that Mary Voytek is still Senior Scientist for Astrobiology, and is currently located part-time in Japan. There is also a US point of contact (POC) at Ames, who can handle the day-to-day activities.

September 24, 2019

PSD Senior Review Discussion

Dr. Verbiscer led a discussion of the results of the PSD Senior Review. To begin the discussion, PAC members individually declared no conflicts of interest associated with the missions covered by the Review, save for Dr. Dana Hurley, a co-I on LRO. Dr. Rinehart also declared no conflicts. Dr. Mainzer offered a general comment on the Review, terming the report as a very detailed, fair assessment of the projects, and agreed that the process could be streamlined per Dr. McNutt's presentation comments.

MEX

Regarding Mars Express (MEX) and its value as a communications relay backup, PAC members were informed that MEX is the only backup relay satellite in Mars orbit (per Mr. Meyer and Dr. Richard Zurek). Dr. Glaze added that Mars Express is an ESA mission, to which the US contributes. Dr. Zurek explained that there is an agreement between ESA and the Deep Space Network (DSN) for some coverage. Dr. Glaze said that any change will require looking at the agreement NASA has with ESA regarding MEX. Mr. Meyer added that he felt that any observations required by the Mars program will be done regardless of fate of Mars Express. Dr. Lyons said that people struggled with this proposal, which was not well-written in terms of science; the descope recommendation had been the review panel's effort to find a silver lining. Dr. Schmidt said she was seeking a unique role for MEX as a functioning mission, that has some utility to the ESA/NASA partnership. Dr. Canup undertook to write a finding stating that the PAC sees insufficient science justification for MEX, but that NASA should consider continuing funding the mission for non-scientific, programmatic, and partnership reasons.

MODY

Dr. Lyons commented that the SRS was enthusiastic about MODY science, but felt that what was more problematic was the implementation, and essentially voted to recommend the overguide proposal rather than the inguide. Dr. Mainzer supported prioritizing the science, and should the funding be available, an upgrade of the System Test Lab (STL). Mr. Meyer said that MODY is a major pipeline for communications, and an asset for landing site reconnaissance. Dr. Mainzer thought it might be helpful to group the programmatic reasoning separately, and focus on it in a paragraph. Dr. Lyons agreed that it would have been helpful to call out the programmatic aspect, but that it was a lot to ask from one panel. Dr. Roberge asked: how do the missions relate to each other scientifically and programmatically? Mr. Meyer noted the review had been constructed to assess only the science value via SMEs. Dr. Glaze commented that the MODY is an aging spacecraft that had had engineering assessments as well, but that this was not the focus of the Senior Review; each mission is assessed individually. Dr. Zurek added that the guidelines for proposals did not explicitly include the scope of programmatic aspects. Dr. Canup thought that the Review called out all the science appropriately, but did not provide enough information to allow the PAC to assess the programmatic aspects.

Dr. Verbiscer summarized the PAC tone as generally endorsing the Senior Review, while issuing a few specific findings on MODY and Mars Express.

Planetary Defense Coordination Office

Mr. Lindley Johnson, Program Director, provided an update on the PDCO. The Center for NEO Studies at JPL keeps a comprehensive data base on known NEOs. The most recent event of note is a newly discovered comet 2I/Borisov, which has been characterized as another interstellar object coming through the Solar System. The comet was initially observed by an amateur astronomer in the Crimea, who has been a contributor for several years. Many of PDCO's initial observations do in fact come in from amateur astronomers.

Discovery statistics to date at PDCO include a total of 20,801 near-Earth asteroids (NEAs) of all sizes. A total of 8778 are in the 140m-plus category. The prediction is that there are about 22-23,000 such bodies, which implies that NASA is about 35% complete in identifying NEAs of the 140m-plus size. NASA has probably found almost every NEO larger than 5 or 6km, and 900 in the one-kilometer-plus category.

Discovery has been tailing off in recent years; NASA is finding only a few per year now. A recent Science and Definition Study (SDT) study established that there are about 940 1km+ objects. The current discovery rate for 140m-plus objects was decreased year, in part due to weather-related viewing issues at various GB facilities. This year only 359 have been found so far. The numbers will not increase unless more assets are brought into play; at this rate, it could take 30 years to meet the Congressional requirement for NEO discovery. The NSF/Department of Energy Large Synoptic Survey Telescope (LSST) is coming online soon, and PDCO will have to learn how to link detections properly to determine orbits. With LSST, NASA could get to the 75-80% range of completion within 10 years of operation. A space-based IR capability will be critical to achieving the goal; IR can easily get objects of 500m or so. Dr. Canup asked if there were some small innovative idea that could help, a SIMPLEx-type opportunity that could be judged on an operational rather than a science basis. Mr. Johnson said that NASA and the National Academies have considered some small satellite ideas, but an ideal telescope would need a large aperture that would not supported by small satellite technology. Dr. Mainzer noted that there are long-period comets whose orbits are poorly understood, and that would require years of detection lead time in order to avert a catastrophe. There is also lack of understanding of the size of NEOs, and whether or not there is a break in the size distribution; these open questions might change what NASA wants to do with future surveys. Mr. Johnson remarked that a NEOCam instrument on the NEOSM spacecraft could triple or quadruple the discovery rate of NEOs.

NEO Earth Close Approaches

In recent years there have been numerous close approaches of NEOs to within 5 million miles of Earth, and some at 14-15 lunar distances (LD). Approximately 70 asteroids have passed between the Earth and Moon during the last year. The object 2019 OK is a 100m object that passed at 0.2LD (72,500km), and was discovered one day before its approach. This object was detected by amateurs (25 July), pointing up the fact that NASA really needs a better capability to discover these objects sooner.

NASA just released its response to the NASEM study on NEOs, which recommended that NASA fund a dedicated space-based IR survey telescope to facilitate NEO discovery and characterization. NASA agreed with the NASEM recommendation, and several other studies have supported this conclusion. NASA also concurred with the recommendation that missions meeting high-priority planetary defense objectives should not be required to compete with high-priority planetary science missions at NASA. NASA will continue to enhance GB observations within the funding profile of PDCO, as well as collaborate with other US and international entities when possible, in detecting and following up on NEOs. PDCO will require more funding, however, to build a space-based IR survey telescope. There is enough funding to continue progress on the instrument, which is the long-lead item for such a telescope. At PDCO's annual \$150M funding level, the launch readiness date (LRD) would be pushed to the late 2020s. In the budget outyears, Mr. Johnson noted that the PDCO funding line in fact decreases.

The NASEM study recommended that all NEO data be archived in a public database. NASA concurred with this recommendation and all major surveys are now archiving their data. Dr. Hurley asked: is this recommendation saying that NASA should prioritize more data in general or just data that NASA wants? Mr. Johnson remarked that NASA takes the stance that if it goes to the trouble of collecting these images, it should get them to the ground. Dr. Mainzer commented that data rates plummet as a spacecraft drifts away from Earth, causing the loss of valuable resolution; going to an interior orbit does not efficiently support the goal of finding 140m objects.

Mr. Johnson briefly detailed the DART project. DART is going well, with no major red flags on the spacecraft. Some of the technology demonstrations have some challenges and may not make it onto the spacecraft, but the kinetic impactor is on track. Dr. Glaze said one of the technology demonstrations is a next-generation ion engine project, and a co-manifest with an international partner. The technology demonstrations need to be ready in Spring 2020. The Infrared Telescope Facility (IRTF) in Hawaii is also

doing well, despite the protests at Maunakea. NASA lost a few weeks of observations, which is characterization work for PDCO, and there was also some negative impact on general Solar System observation science.

There are some concerns about the continuing operation of the Arecibo radar facility and the prospect of considerably reduced funding from NSF (decreasing from \$8M to \$2M per year). The University of Central Florida (UCF) has taken over management of Arecibo, and things have stabilized, but there is no viable plan to ensure future funding from the state of Florida. Interplanetary radar capability is threatened by this situation. Dr. Glaze added that the issue has been on the table for some time; NASA PSD contributes \$5M per year to Arecibo, about 50% of the funding required. There are also some ionospheric science funds from NSF, very little (\$1M or so). Dr. Mainzer commented that if NASA PDCO is paying for time on these assets, it should own that time. Mr. Johnson noted that there are interrupt procedures in place at IRTF when it is necessary to observe and characterize a significant object; he felt observers were getting the time they need. Dr. Roberge asked: if NSF is required to help out on PD, why are they not doing this? Mr. Johnson said that NSF is not addressing the obligation in their budget submittal. He added that if Arecibo disappears, NASA will continue to use the Goldstone antenna. He commented that for any object PDCO thinks is a threat, it will need a variety of assets to venture an assessment that is beyond a wild guess.

Mercury Analysis Group

Dr. Shoshana Weider, a MESSENGER (Mercury Surface, Space Environment, Geochemistry, and Ranging) scientist currently detailed to NASA, presented some background on Mercury exploration to date. Mariner 10 performed three fly-bys in the 1970s. The MESSENGER spacecraft also did three flybys before its 3.5-year orbital mission around the planet began in 2011 and completed in 2015. The ESA spacecraft BepiColombo is now on its way to Mercury, with six flybys planned before it goes into orbit in December 2025, for a roughly one-year mission. The MESSENGER Science Team recently published a 20-chapter book, entitled *The View*.

The Mercury community has been active. The current and future science of the innermost planet was the subject of a conference held in May 2018. Several more Mercury-focused conferences are in work, and a Mercury email listserve has been established, now with 140 members. A community white paper was published in 2018, with 68 signatories. The community is also preparing and modifying papers in advance of the Decadal Survey. A BepiColombo AO for Interdisciplinary Scientists and Guest Investigators was released earlier this year, to augment science return and enable cross-disciplinary participation. The AO was open to proposers in Europe, Japan and the US. NASA funding is available for select US investigators. Appointments are likely to be confirmed by November 2019, and additional AOs are possible.

High-priority questions for Mercury have been determined by a recent *ad-hoc* committee headed by Steve Hauck, which engaged the wider Mercury community and attracted more than 30 responses. The resultant questions have much intersection with the general, big-science questions for planets. In summary, Dr. Weidner concluded that Mercury science is still flowing, with substantial interest in the planetary science community. Efforts are under way need to work out terms of reference (TOR) for a new Mercury Analysis Group (AG). Dr. Glaze expressed her approval of the new AG, and said that as other AGs are now up and running Decadal Survey studies, the new Mercury AG presents a good opportunity to establish consistency and concordance with other AGs. She said she would be taking ownership of the process, and would try over the next six months to get the AG secretaries together to get the job done.

GPRAMA

Ms. Jennifer Kearns presented background information on the GPRAMA process, which established rules for annual federal agency performance plans and reports. GPRAMA stands for the Government

Performance and Results Modernization Act. The PAC went on to assess the five annual performance indicators (APIs) for PSD, and voted on the outcomes using Green, Yellow and Red ratings. “Green” signifies that expectations for the research program were fully met within the context of resources invested. “Yellow” signifies notable or significant shortfalls in progress, but an achievement of worthy scientific advancement. “Red” signifies major disappointments or shortfalls in scientific outcomes, and the absence of notably positive results. Details of the APIs, discussion, and voting follows:

- API PS-19-1 Demonstrate planned progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact, and evolve.
- API PS-19-2 Demonstrate planned progress in exploring and observing the objects in the solar system to understand how they formed and evolve.
- API PS-19-4 Demonstrate planned progress in exploring and finding locations where life could have existed or could exist today.
- API PS-19-5 Demonstrate planned progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.
- API PS-19-6 Demonstrate planned progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.

API PS-19-1

Vote for Green- unanimous

API PS-19-2

Vote for Green- unanimous

API PS-19-4

Dr. Schmidt felt that a paper on the magnetic signatures at Europa did not fit the life question as represented in the API, and offered to provide more relevant data on Titan and Enceladus. Dr. McCubbin suggested replacing a Gale Crater reference with a peer-reviewed article.

Vote for Green- unanimous

API PS-19-5

Vote for Green- unanimous

API PS-19-6

There was some discussion among the PAC as to what constitutes true progress in the planetary defense arena. Dr. Hurley commented that lunar work was absent from the supporting data under this API. Ms. Kearns noted that it is clear that PDCO will fall short of its target, a fact that will be reflected in a separate part of the GPRAMA report. She explained that NASA carries multi-year performance goals at a higher level than the GPRAMA indicators, which take into account the committee GPRAMA ratings as well as other sources of assessment. Ms. Kearns provided information about the number of objects discovered by PDCO this year vs. target. Dr. McCubbin offered to provide data about meteoroid impacts that are relevant to bombardment history in the Solar System. Dr. Mainzer cited another paper about impacts on Mars. Dr. Hurley offered Lunar Reconnaissance Orbiter Camera (LROC) data about new craters on the Moon, and other data on lunar volatiles. The PAC judged the API as a Green, given that the target shortfall is covered under a different section of the GPRAMA report. Dr. Roberge suggested that the word “identify” be removed from the API in the future.

Vote for Green- unanimous

VEXAG

Dr. Darby Dyar, Chair of the Venus Exploration Analysis Group (VEXAG), presented. Venus is believed to have had liquid water for 3B years, and also has signs of nascent plate tectonics, making it an interesting Earth analogue. Currently, there are lower resolution topographic data for Venus than exists for Pluto, arguing for further exploration of Venus. VEXAG is looking to provide support for the Decadal Survey, build a Venus program, a community of Venus scientists, and to reach out to the public as well. VEXAG has produced final drafts of goals, objectives and investigations documents. Current science objectives for a Venus mission are to understand early evolution and potential habitability; to understand the planet's atmospheric composition and dynamics; and to understand geologic history and rock type. The Roadmap for Venus Exploration contains near-term, mid-term and far-term goals that are tied to ranges of rovers, landers, balloons, etc. The Venus Technology plan enumerates what is necessary to get there. VEXAG is also preparing 24 white papers, with drafts scheduled to be done by November 2019. The High Operating Temperature Technology (HOTTech) Program is developing high-temperature technologies for Venus and other targets with extreme environments. There is also a small, independent Long-Lived In Situ Solar System Explorer (LLISSE) lander that is being developed at Glenn Research Center, a lander that can survive for 60 days on the Venusian surface, and which could conceivably travel on the Russian mission-in-development, Venera-D. NASA Ames Research Center has developed a Heat Shield for Extreme Entry Environment (HEEET) fabric technology, suitable for a heat shield for atmospheric entry into Venus. Dr. Glaze noted that there are other applications for HEEET, such as MSR or a Saturn probe. The Glenn Extreme Environments Rig (GEER), recently upgraded, is now being used as a Venus simulator. A new instrument, the Venus Elemental and Mineralogical Camera (VEMCam), represents great advances in Venus spectroscopy. VEMCam takes advantage of carbon dioxide spectral windows in the Venusian atmosphere to enable the study of geology on the planet, and was developed by the New Frontiers program. In other areas, VEXAG will be hosting an *Exoplanets in Our Backyard* conference in February 2020, and will be investigating ride-along opportunities on the Dragonfly and Europa Clipper missions, as they will both use gravity assists at Venus.

Dr. Dyar highlighted a number of VEXAG findings, requesting PAC advocacy for clarity in determining ride-sharing for future Venus probes, and support for programmatic balance. VEXAG also requests that the PAC help to underscore the importance of US leadership in Venus missions, consider workforce issues (e.g., addressing disproportionate representation from NASA centers), and support for the funding of fundamental science to understand not only the "what" but "why."

Small Bodies Analysis Group (SBAG)

Dr. Michael DiSanti presented results from the latest Small Bodies Analysis Group (SBAG) meeting, which seeks input from the broader community on SBs and missions to SBs. The SBAG charter lists asteroids, comets, and includes Centaurs, etc. The SBAG meets twice yearly. Its last formal document was completed in 2016, and is being revised at present. Completed and revised goals will be posted on the SBAG website by the end of 2019. SBAG's three goals encompass the categories of Science, Planetary Defense, and Exploration. Current missions to small bodies include the Osiris-Rex mission to Bennu, New Horizons, Hayabusa-2, and NEOWISE. Future missions include the Lucy and Psyche missions selected in the Discovery Program in 2017, the DART mission, the JAXA Destiny mission, and a Comet Interceptor, a joint mission between NASA and ESA, to launch in 2028.

June and January SBAG findings include support for the extensive community effort in studies for future small bodies missions and recommends assessing the feasibility of such missions prior to serious consideration and inclusion in the Decadal Survey; support for the recently allocated, separate Planetary Defense budget in NASA's Planetary Science Division budget; encouragement to NASA to open New Frontiers calls to all targets, or to establish a transparent procedure for determining what targets will be allowed, and support for high-quality studies of potential small bodies missions as part of the pre-Decadal

Survey process. Dr. DiSanti emphasized a significant June 2018 finding that noted the lack of SBs in a recent report of the International Space Exploration Coordination Group (ISECG).

SBAG developed a number of big questions to be considered by the Decadal Survey:

- What do small bodies tell us about the formation of the Solar System and the conditions in the early solar nebula?
- What does the distribution, composition, and sizes of small bodies tell us about the evolution of the Solar System, including its dynamical history, cratering processes, and the influx of volatiles and organics into the inner Solar System?
- Do sustainable habitable environments exist on any of the small bodies?
- What are the main geological processes that determined the evolution and current state of the small bodies and are they similar to those on larger bodies?
- What threat do Near-Earth Objects pose to Earth?

SBAG does not wish to foster competition between PSD and PDCO, and therefore seeks to concentrate on discipline-specific questions.

Outer Planets Analysis Group (OPAG)

Dr. Linda Spilker, the Outer Planets Analysis Group (OPAG) Vice Chair, presented. OPAG provides a community-based forum to provide science input, and will hold its next meeting at the Lunar Planetary Institute (LPI) in February 2020. OPAG and SBAG hold “joint custody” of Pluto and other bodies in the Kuiper Belt. Key activities of the OPAG since February 2018 include a workshop on subsurface needs for Ocean Worlds, the Dragonfly selection for the NF#4 call, the completion of the 21st orbit of Jupiter by the Juno probe, program design review (PDR) completion for the Europa Clipper, and the progression of the ESA JUPITER ICy moons Explorer (JUICE) mission to its 2022 launch. A 2018 OPAG goals document was revised with several new sections, and an introduction containing more detailed information on Ocean Worlds.

Priority technologies for Outer Planet exploration include Instrument Concepts for Europa Exploration (ICEE), Homesteader, multi-mission investment in highly efficient radioisotope power systems, lightweight solar arrays, miniaturization and new life detection instrumentations, and low-power, high-data rate Ka band communication systems. OPAG’S most recent key findings by category are to quickly execute OP mission studies prior to start of Decadal Survey, and to commission a workplace climate survey.

A recent science finding of significance is the accumulation of radar evidence of 100 meter-deep methane lakes on Titan, which are located hundreds of meters above “sea level.” These small Titan lakes are theorized to be explosion craters, caused by warming nitrogen exploding outwards.

Mars Exploration Program Analysis Group (MEPAG)

Dr. Aileen Yingst, Mars Exploration Program Analysis Group (MEPAG) Chair, presented the briefing. MEPAG has an Executive Committee and a Goals Committee, representing a wide variety of expertise and experience. MEPAG holds one to two face-to-face meetings per year, with virtual meetings in between. Recent significant activities include Mars community “meet-and-greets” at the last few Lunar and Planetary Science Conference (LPSC) events; presence at the Council on Outer Space Research (COSPAR) meeting in July 2018; an American Geophysical Union (AGU) poster presentation; and contribution to the recent Ice and Climate Evolution Science Analysis Group (ICESAG) report. MEPAG released a Goals document in October 2018, with the next to be delivered in March 2020, for input to the Decadal Survey. MEPAG is also assisting with mid-term reviews, in the community response with big

questions for the next Survey, and it participated in the most recent CAPS discussion. MEPAG is providing Google Docs form for white papers.

Of note, MEPAG had been concerned about the absence of high-level commitment to MSR, the highest priority of the MEP. This concern was allayed in 2017, and there is now a FY19 line. MEPAG is also excited about the NASA/ESA agreement on MSR development. A second concern had been a lack of program definition, such as for polar climate science, thus the MEPAG was pleased to learn of the creation of a MEP strategic architecture panel. The AG has an ongoing concern with the aging communication infrastructure around Mars. ODY is running on backup power, MRO batteries are life-limiting, and MAVEN is also aging. Extended Mars missions are being threatened by overruns on Mars 2020. The community believes it is essential to get M2020 to launch without delay. A delayed Senior Review prevented timely input into extended mission reviews, adding to concern about funding for extended mission science.

Key MEPAG findings recognize the progress being made in MSR. In addition, M2020 is on schedule, and there have been new and ongoing discoveries that challenge previous views of Mars. MEPAG continues to be concerned about aging infrastructure. Dr. Spilker emphasized that MEPAG is ready to respond to calls for assistance with Mars program planning and analysis.

Mapping and Planetary Spatial Infrastructure Team (MAPSIT)

Dr. Justin Hagerty presented a briefing on the new Mapping and Planetary Spatial Infrastructure Team (MAPSIT), which was established in response to the need for maximizing scientific return from missions, and helping users to discover and use science-ready data. MAPSIT centers on the production of spatial data and science-ready spatial data products, and foundational and framework data products. A total of five MAPSIT findings can be found on the LPI website; two key findings are that NASA missions should be encouraged to obtain high-quality data that can be incorporated into foundational data products, and to deliver data in formats that are easily usable.

Lunar Exploration Analysis Group (LEAG)

Dr. Samuel Lawrence, Chair for the Lunar Exploration Analysis Group (LEAG) presented. LEAG is jointly chartered by HEO and SMD, with STMD participation. LEAG has a Commercial Advisory Board Steering Committee, and has appointed chairs for lunar surface operations, in-situ resource utilization (ISRU), and work force issues. LEAG typically holds its annual meeting in the Fall. Major concerns of the LEAG include the recognition that the lunar community needs another generation of leaders, and therefore mechanisms must be established to get early career scientists to the major discipline meetings: one mechanism is the Bernard Ray Hawke travel stipend, and the other is the Larry Taylor award for undergraduates. In 2017 and 2018, LEAG took a comprehensive look at the state of lunar science and exploration, resulting in a number of reports that were written by a diverse and inclusive set of participants.

The year of 2019 has been busy: CLPS providers are now under contract, selections have been made in the Development and Advancement of Lunar Instrumentation (DALI) program; ANGSA teams have been selected; SIMPLEX activities are under way; and LRO continues operations LEAG is very pleased with SMD efforts to reach the lunar community. The 2018 LEAG meeting was wildly successful thanks to a new format, and strong participation in which 27 lunar mission concepts were presented. The Lunar ISRU meeting of 2019 had 200 attendees. The community has been involved in a Big Questions thought exercise, and is preparing white papers for Astro2020. A Lunar Capabilities Roadmap draft is under review, and a Volatiles Measurement (VM) Special Action Team has been stood up to provide input for the next Decadal Survey. LEAG wants to establish more VM teams; the first one will be on mission concepts.

Dr. Lawrence briefly reviewed recent LEAG findings:

LEAG finds that SMD has made impressive progress in implementing PSPD-1, and must continue to enable the cis-lunar community. LEAG also fully supports Project Artemis, for which the LEAG Lunar Exploration Roadmap is one of the guiding policy frameworks. Dr. Lawrence notes that the LEAG community is standing by to assist the Project. Other findings addressed Big Questions that have not been addressed by previous Decadal Surveys, such as those surrounding the identification of resources and hazards of the Solar System, and their implications for human exploration. LEAG issued a finding on new implementation opportunities, stating a preference for allowing NASA to choose implementation pathways, while the Survey focuses on science questions. LEAG also finds that New Frontiers priorities should be determined by the decadal process. LEAG will hold its next meeting in Washington, D.C. at the end of October, when it will focus on planning for the Decadal Survey and for future Human Exploration (Project Artemis).

Curation and Analysis Planning Team for Extraterrestrial Material (CAPTEM)

Dr. Kevin McKeegan presented. CAPTEM is a community-based, interdisciplinary forum that meets at least twice per year, and is concerned with the collection, curation, and allocation of NASA extraterrestrial sample collections, including Antarctic meteorites. CAPTEM also functions as a standing review panel, and organizes ad-hoc or standing subcommittees to address specific issues, such as supporting HEO goals related to the collection of new samples. Dr. McKeegan reviewed CAPTEM membership, and briefly detailed subcommittees covering lunar materials, asteroids, cosmic dust, the Stardust project, meteorites, informatics, and a Mars sample return (NASA and ESA). In the next decade, Curation will receive five new collections: OSIRIS-REx, Hayabusa-2, lunar, martian, and the JAXA Martian Moons eXploration (MMX) mission to Phobos and Deimos. Recent CAPTEM activities include providing integrated reviews for ANGSA, and the completion of a review of the OSIRIS-REx initial curation plan by the asteroid subcommittee. CAPTEM will formally invite a JAXA representative to CAPTEM's Spring meeting, to help improve coordination of sample curation and sharing. The most recent CAPTEM findings were associated with the initial curation plans for OSIRIS-REx, which were delivered to the O-Rex team, and which were largely technical. One finding dealt with the philosophical approach to sample-sharing. The current and principal issue carried by CAPTEM is recognizing that new collections of extraterrestrial samples of various types and sizes are in the pipeline, for which CAPTEM stands ready to help when needed, and to anticipate NASA strategies for new analytical capabilities. CAPTEM findings on Informatics, and preparations for a future MSR curation facility are also of note: What is the role of CAPTEM in MSR; what are the interfaces; and what is CAPTEM's role with respect to ESA?

AGs Discussion

Dr. Canup suggested that the LEAG's Big Question exercise include the latest lunar action team reports. Dr. Glaze commented that the idea for LEAG's Big Questions was to stay broad. Mr. Meyer asked if the intention was to have the Survey answer these questions. Dr. Glaze said the idea had been to determine whether the community could converge on a fixed number of high-level questions, thereby revealing synergies between destination-focused groups, and where the science gaps lie. This approach is in effect responding to grass-roots interests in the community, and seeing whether the Decadal Survey is amenable to the approach, as opposed to a target-based approach. Dr. Glaze thought it would be valuable to identify the big questions, and decide which targets best answer these questions. Dr. Schmidt said that target-based approaches discourage interdisciplinary research, and always leaves out astrobiology. Dr. Schmidt also pointed out that sounding radar data was not quite a mapping product, but was often interpreted like imaging data, which is often incorrect. It is different from surface radar, in that the processing is very important; members that have the processing power for sounding radar are usually favored (in selections). Earth Science has the same issue; Dr. Schmidt did not think that the Planetary community was very careful about the distinction. Dr. Hagerty commented that if sounding radar had not been specifically

discussed, he could bring it to the table. He added that as to concerns about the GIS software, MAPSIT's goal is to make everything as open-source as possible.

Dr. Hurley commented that several AGs mentioned workforce and diversity issues, and asked if anyone on the PAC had identified pressing needs in these areas. Dr. Filiberto noted that there is now an inter-AG study on diversity and inclusivity, whereby the AGs are joining forces to write a white paper. The AGs are ramping up to look at the pipeline in the planetary community. Dr. Glaze thought the state of the profession should also be part of the Decadal Survey deliberations, and that the AGs could do a good job collecting this information, as opposed to "death-by-survey." Dr. Lyons felt that VEXAG should take its list of 24 white papers and consolidate it. Dr. Glaze agreed that efficiency is gained by having one paper with 24 authors, rather than 24 papers with separate authorship. Dr. Roberge noted that Astro2020 said they had set up panels depending on the number of topic papers. Dr. Glaze said she would include explicit guidance on this issue in the statement of task to the NAS.

Findings and Recommendations

The PAC discussed findings and recommendations. Dr. Stroud undertook to write a finding endorsing the Senior Review recommendations in terms of rankings, and specific comments on the possibility of creating a UFE pool; a finding secondary to this was a statement supporting a mission-independent line to support a Mars data portal. The current portal is funded by THEMIS. The committee agreed to the gist of the findings, and agreed to edit by email.

Dr. Canup drafted a finding on the Mars Express Senior Review outcome, stating that the PAC sees insufficient scientific evidence to support extending the Mars Express mission, and suggesting NASA investigate other programmatic reasons for such an extension.

Dr. Hurley drafted a travel finding, stating that NASA should do what it can to help NASA contractors share their work with the community, and to alleviate travel restrictions in a timely manner.

Dr. Canup suggested finding addressing the different selection and funding percentages across the R&A programs, and whether a higher-level assessment should be made to rebalance the program. Another issue was the difficulty in staffing review panels, reducing the burden on Headquarters and the community during proposal season. Dr. Roberge recommended taking a look at what the APD review process is for allocating observation times. Dr. Mainzer suggested simplifying the process by shortening proposals, doing more of the review work upfront, and using external reviews to deal with Co-Is on one-off topics. Dr. Canup drafted the finding.

Dr. Stroud commented that the AG chairs had mentioned they felt unheard in the GPRAMA process, and asked whether a finding on the subject was necessary. Dr. Roberge recommended that the AG chairs be contacted before the GPRAMA exercise, or sending the completed GPRAMA report to the AG chairs. Dr. Glaze emphasized that AG chairs submit science "nuggets" throughout the year, as do the NASA Program Officers.

Dr. Mainzer suggested a finding on whether the Decadal Survey should be focused on the science questions or on targets/destinations. Dr. McCubbin added the issue of opening the New Frontiers program, adding that there are some differing opinions on the influence of centers. Dr. Glaze said the centers will base their proposals on what they think will win. Dr. Roberge asked if NSF would have to agree to the question focus vs. the target focus. Dr. Glaze said she would discuss the approach with them, and did not expect a great difference of opinion. Dr. Hurley thought that Flagship missions inherently address numerous science questions, and that another drawback of the question approach is the difficulty in ensuring that a panel will be balanced in representation. Dr. Schmidt felt that over-strategizing can result in losing a mission. Dr. Roberge commented that one mission could be everyone's second favorite,

and therefore lose. In a target-based system, exoplanets will always lose. Dr. Mainzer thought maybe just a finding encouraging the community to engage with the Decadal Survey. There was little PAC support for a specific finding. Dr. Mainzer suggested a “thumbs-up” cheering statement, to general agreement.

Dr. McCubbin suggested a finding stating that the ground element of MSR effort has been well characterized by the MEPAG, and recommending that CAPTEM work with MEPAG closely to avoid duplication of effort. The PAC agreed to this finding.

Dr. Schmidt suggested a finding on the implementation plan for MSR and associated ground-based facilities, noting that there has been a perennial problem with access to samples and analysis, and that larger, wealthier institutions with large analysis facilities are unfairly weighted to win proposals. The broadest swath of the community should have access to sample and analytical facilities. Dr. McCubbin noted that distribution and access to samples are specifically codified in NASA policy. Dr. Glaze expected that MSR will necessitate researchers going to a containment facility, and once the samples have been cleared for approval, they can be dispersed. Dr. Verbiscer felt a finding was premature at present, and should wait until NASA commits to MSR. The PAC agreed.

Dr. Mainzer recused herself from a discussion of a PAC finding on NEOCam, leaving the meeting room for the duration. Dr. Roberge said that the situation with the original, PI-led NEOCam instrument seems confusing and unusual, in that it received a phase A award, and has now become a directed mission to JPL. It is critical to maintain the science leadership, and the PAC should understand how the science will be reconstituted. The current understanding is unclear, and constitutes a serious omission. Dr. Glaze did not discourage a finding, but felt the PAC should understand that it is premature to discuss the issue. Drs. Verbiscer and Roberge said they would like to see the science plan when there is one to present. Dr. Schmidt felt there should be an opportunity for the science community to participate in directed missions, and supported a finding that identifies a mechanism by which some science leadership could be enabled in such missions. Dr. Roberge drafted the finding.

A finding suggested by Dr. Stroud on NSPIRES vs. MARIE databases was moved to a future agenda.

Public comment period

No comments were noted.

Wrap-up

Dr. Verbiscer adjourned the meeting at 4:50 pm.

Appendix A

Attendees

Planetary Science Advisory Committee Members

Anne Verbiscer, **Chair**, University of Virginia
Amy Mainzer, Vice Chair, University of Arizona
Robin Canup, Southwest Research Institute (SwRI)
Justin Filiberto, Lunar and Planetary Institute
Justin Hagerty, United States Geological Survey
Dana Hurley, Johns Hopkins Applied Physics Laboratory
Timothy Lyons, University of California, Riverside
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 HQ

NASA Attendees

Steve Clarke, NASA HQ
Doris Daou, NASA HQ
Elaine Denning, NASA HQ
Michael DiSanti, NASA HQ
T. Jens Feeley, NASA HQ
Lori Glaze, NASA HQ
Ed Grayzech, NASA GSFC
Lindsay Hays, NASA HQ
Bill Knopf, NASA HQ
Sean McCarville, NASA HQ
Michael Meyer, NASA HQ
Sarah Noble, NASA HQ
Mitch Schulte, NASA HQ
Linda Spilker, JPL-Caltech
Henry Throop, NASA HQ
Shoshana Weider, NASA HQ
Richard Zurek, JPL-Caltech

Non-NASA Attendees

Francis Bordi, Aerospace
Darby Dyar, Mount Holyoke College
Mary Floyd, Electrosoft, Inc.
Amitabha Ghosh, Tharsis, Inc.
Samuel Lawrence,
Doug McCuiston, McQTech, LLC
Ralph McNutt, Jr., JHU APL
John Mester, University of Arizona
R. Aileen Yingst, PSI
Joan Zimmermann, Zantech, Inc.

Webex Attendees

Linda Billings, NIA
Nancy Chabot, Applied Physics Lab
Stephen Clark, Space Flight Help Desk
Roberto Conti, Ball Aerospace
Brett Denevi, JHU APL
Rudy Frahn, SWRI
Christina Gibbs, KBR
Zach Girazia, University of Iowa
Cesare Grava, SWRI
Mary Gunther
KC Hampton, NASA HQ
Elizabeth Howell, Space.com
James Howell, Godsend Tech
Lilly Larson, Ball Aerospace
James Lochner, USRA
Kevin McKeegan, UCLA
David Millman
Betsy Pugel, NASA HQ
John Rummel, SETI
Kurt Retherford, SWRI
Marcia Smith, SpacePolicyonline.com
Jared Stout, Vineable LLC
Julie Taftallio, NASA JPL
Tommy Trab, Planetary Science Institute
Ellen Thurgood, SEL
Richard Vingel, MIT
Paul Voose
Lisa Wood, Ball Aerospace

Appendix B Committee 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 Institute

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

Planetary Science Advisory Committee Meeting

September 23-24, 2019
NASA Headquarters, Room 3D42
Washington D.C.

Monday, September 23, 2019, 8:30 a.m. – 5:00 p.m.

- 8:30 Opening, Announcements, Around the Table Identification
- 8:35 SMD Welcome and Updates (T. Zurbuchen)
- 9:35 PSD Status Report (L. Glaze)
- 10:30 Break**
- 10:45 PSD R&A Status (S. Rinehart)
- 11:30 Lunar Program (S. Clark, S. Noble)
- 12:00 Lunch**
- 1:00 PSD Senior Review (B. Knopf)
- 3:00 Break**
- 3:15 Mars Program (J. Watzin)
- 3:45 Discussion
- 5:00 Adjourn**

Tuesday, September 24, 2019, 8:30 a.m. – 5:00 p.m.

- 8:30 Agenda Updates & Announcements
- 9:00 Planetary Defense Coordination Office (L. Johnson)
- 10:00 Mercury AG (S. Weider)
- 10:30 Break**
- 10:45 GPRA-MA
- 12:00 Lunch**
- 1:00 VEXAG (D. Dyar)
- 1:15 SBAG (M. DiSanti)
- 1:30 OPAG (L. Spilker)

1:45	MEPAG	(A. Yingst)
2:00	MAPSIT	(J. Hagerty)
2:15	LEAG	(S. Lawrence)
2:30	CAPTEM	(K. McKeegan)
2:45	AGs Discussion	
3:15	Break	
3:30	Findings and Recommendations Discussions	
5:00	Adjourn	

SUPPLEMENTARY INFORMATION:

DATES

Monday, September 23, 2019, 8:30 a.m. – 5:00 p.m.

Tuesday, September 24, 2019, 8:30 a.m. – 5:00 p.m.

ADDRESS

NASA Headquarters, Room 3D42, 300 E Street, SW, Washington, DC 20546

TELECON (same both days)

USA toll free conference number 1-800-779-9966, passcode 5255996

Toll number also is available, 1-517-645-6359, passcode 5255996

WEBEX

The WebEx link is <https://nasa.webex.com/>

September 23: Meeting number is 904 816 731 and password is PAC@Sept23 (case sensitive)

September 24: Meeting number is 903 388 535 and password is PAC@Sept24 (case sensitive)

Appendix D Presentations

1. Science Mission Directorate Update; *Thomas Zurbuchen*
2. Planetary Science Division Research and Analysis Status; *Stephen Rinehart*
3. Lunar Discovery and Exploration Program; *Brad Bailey*
4. PSD Senior Review Subcommittee; *Ralph McNutt*
5. Mars Exploration Program Status; *James Watzin*
6. Planetary Defense Coordination Office; *Lindley Johnson*
7. Mercury Analysis Group; *Shoshana Weider*
8. Small Bodies Analysis Group; *Michael DiSanti*
9. Outer Planets Analysis Group; *Linda Spilker*
10. Mars Exploration Program Analysis Group; *Aileen Yingst*
11. MAPSIT Briefing; *Justin Hagerty*
12. Lunar Exploration Analysis Group; *Samuel Lawrence*
13. Curation and Analysis Planning Team for Extraterrestrial Material; *Kevin McKeegan*
14. Venus Exploration Analysis Group; *Darby Dyar*