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Meeting Minutes

Jonathan Rall, Executive Secretary

Janet Luhmann, Chairman

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Welcome, Agenda, and Announcements

Dr. Jonathan Rall, Executive Secretary of the Planetary Science Subcommittee (PSS), opened the meeting at 8:30 a.m. and made administrative announcements. Dr. Janet Luhmann, PSS Chair, called the meeting to order and asked the PSS members to introduce themselves, as several new members were present. After the introductions, Dr. Luhmann thanked for their service the three members who will be rotating off the PSS after this meeting (Nancy Chanover, Candice Hansen-Koharcheck, and Christopher House).

Dr. Luhmann asked Dr. James Green, Director of the Planetary Science Division (PSD), to describe how he sees the role of this subcommittee, in the context of other advisory input he receives. Dr. Green began by describing how NASA sees the various advisory bodies and committees with which PSD works. Under a Congressional mandate, the Planetary Science Decadal Survey is developed by a study committee of the National Academies of Sciences, Engineering, and Medicine (the National Academies).¹ Between Decadal Surveys, a standing committee of the National Academies, the Committee on Astrobiology and Planetary Science (CAPS), serves as the “keeper” of the Decadal Survey. The next CAPS meeting is scheduled for the end of March. The Decadal Surveys and CAPS are focused on strategies and long-term approaches, Dr. Green explained, and they don’t get down to the level of tactical advice on issues such as working through tight budgetary conditions or details of how the program evolves. NASA and PSD look to the advisory structure, including the PSS and the Assessment/Analysis Groups (AGs), to provide PSD with that kind of tactical advice. This meeting in particular, he said, will have a lot of tactical discussions. He looks for input from the PSS, through its findings, on how to get the most science for PSD’s budget dollars. He views the PSS as the top-level advisory body for tactical findings that are important for guiding “the Titanic around the iceberg, rather than just rearranging the deck chairs.” The NASA Advisory Council (NAC) Science Committee and subcommittees structure provides critical input for the division’s decisions, and he wants the discussions to be open to any ideas. The importance of PSS, Dr. Green added, will be demonstrated at this meeting.

Dr. Nancy Chabot asked to allow the new chair of the Outer Planets Advisory Group (OPAG), Dr. Alfred McEwen, to be seated at the table with the PSS members. Dr. Green explained that the appointment process for Dr. McEwen (and another newly elected chair of an AG) under the Federal Advisory Committee Act (FACA) was not yet completed, so he could not yet join in PSS discussions as a member. After further discussion, the PSS passed a unanimous motion to give the AG representatives present (or on the telephone conference line) who were not yet formal PSS members priority in responding when topics were opened up for comment from visitors.

In response to a question from Dr. Clive Neal on the status of the AGs, Dr. Green said that no changes to the AG structure were under consideration and PSD would support their meetings through the conference mechanism. Although the findings and input from the AGs will no longer be passed forward as *formal* findings in the way they had been in the past, PSD staff will continue

¹ The most recent Planetary Science Decadal Survey, *Vision and Voyages for Planetary Science in the Decade 2013-2022*, was published in 2011, and is available from The National Academies Press at www.nap.edu/catalog/13117/vision-and-voyages-for-planetary-science-in-the-decade-2013-2022.

to attend the AG meetings, and the input from the AGs to the PSS will continue to be taken as valuable input from the disciplinary communities they represent. Dr. Green suggested that it would be good to have further discussion on how to more easily support the AG meetings and special studies that assessment teams undertake. Dr. Rall explained why the new support mechanism for the AGs required submission and approval of a conference proposal. After further discussion, there was general agreement that periodic submission of a proposal that would include all the AG meetings scheduled for a given period may be a good way to streamline the process.

Dr. Luhmann noted that not all PSS members are AG chairs, and all PSS members are here to provide advice as individuals. Therefore, she requested that members who were also AG chairs distinguish between their comments as individuals and PSS members versus comments that report the views of their AG constituency. She noted that findings from the PSS could be directed to the Science Mission Directorate (SMD) and NASA as a whole, not just to the Planetary Science Division of SMD, particularly if findings are considered and accepted by the NAC Science Committee, on which she sits. Because the NAC Science Committee is meeting at NASA Headquarters at the end of this week, she added, it will be important for the PSS to formulate and approve by Thursday afternoon any findings it wants Dr. Luhmann to present before the Science Committee on Friday.

Dr. Luhmann then gave the floor to Dr. Green to update the subcommittee on PSD programs and missions and to respond to the PSS findings from the October 2015 meeting.

PSD Status Update and Findings Response

Dr. Green said his briefing would concentrate on some topics in the PSD missions and go-forward plans, as there will be an extensive briefing on the PSD Research and Analysis (R&A) program immediately following his briefing. He began with an overview slide showing current missions and those in formulation and implementation.

Among international collaborative missions, PSD is working with the European Space Agency (ESA) on formulation of the JUpiter ICy moons Explorer (JUICE) to Ganymede and implementation for the Bepi/Colombo mission to Mercury. The Rosetta mission with ESA is winding down as it follows comet Churyumov-Gerasimenko, which is now on the outbound portion of its orbit. In the Mars program, ESA collaborations include Mars Express (now in extended operations) and implementation for ExoMars 2016 (Trace Gas Orbiter, TGO) and ExoMars 2018 (rover mission). PSD is also working with the Indian Space Research Organization (ISRO) on their plans for a Mars mission and how PSD might work together with ISRO.

FY 2016 Appropriations and the President's FY 2017 Budget Request

Dr. Green said that Congress's FY 2016 appropriation supports a robust planetary science program. PSD received \$1.63 billion, which is \$270 million more than the President's Budget Request for FY 2016. He credited the work of everyone involved in communicating with the public for the tremendous public interest in planetary science, which is reflected in the support from Congress and the Administration. Within the PSD budget, \$277 million is directed to planetary science research, which includes the R&A program. The Discovery Program received \$189 million (a plus-up of \$33 million over the President's request), including full funding for the

Lunar Reconnaissance Orbiter (LRO); New Frontiers received \$259 million; the Mars program received \$448 million (a plus-up of \$36 million), including full funding for the Opportunity rover mission; \$197 million was directed to the Technology program (a plus-up of \$55 million) and includes \$25 million for icy satellites surface technology. The \$261 million for Outer Planets (a \$145 million plus-up) came with direction to launch the Europa mission on the new Space Launch System (SLS) by 2022 and to include a lander (with a budget of \$175 million for the Europa effort) in that mission. The appropriation included direction that NASA fund a joint study with ESA for a mission to an asteroid (mission concept combines two earlier concepts: Asteroid Impact & Deflection Assessment [AIDA] and the Double Asteroid Redirection Test [DART]). DART would be the NASA portion of the mission and would study how an impact on the secondary asteroid in a binary system would change the orbit of that body (diameter is about 140 meters). The objective is to understand how kinetic impactors could be used in a mitigation strategy to avoid an asteroid-Earth collision. Congress also directed NASA to establish a new Ocean Worlds program “with a primary goal to discover extant life on another world using a mix of Discovery, New Frontier, and flagship class missions.”

The FY 2017 President’s Budget Request, Dr. Green said, represents a much healthier planetary science program than prior-year requests and projections. This notional budget (details can change as the current fiscal year unfolds) continues development of the Mars 2020 mission; funds continued formulation of the Europa mission; continues work on the JUICE instrument; initiates studies for the next New Frontiers mission (NF 4); continues operation of the Juno and New Horizons missions; operates 13 planetary missions, including five Mars missions (Mars Atmosphere and Volatile Evolution Mission [MAVEN], Curiosity, Opportunity, Odyssey, and Mars Reconnaissance Orbiter) the Cassini mission to Saturn, and Lunar Reconnaissance Orbiter (LRO); increases support for technology development to accelerate future power systems, and increases support for the R&A program.

Discovery Program

In the Discovery Program, the still-active missions are Dawn, which remains in orbit around the dwarf planet Ceres; LRO in orbit around the Moon; Strofio, which has been delivered to ESA for the Bepi/Colombo mission to Mercury; and the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSIGHT) mission to Mars.

Problems with instrument development kept InSIGHT from making its original March 2016 launch window. A NASA announcement on InSIGHT (released concurrently with Dr. Green’s statement about it to the PSS) states that a way has been found to move to a 2018 launch. Dr. Green described the constraining factor of infrequent launch windows for planetary missions—compared with missions in Earth science, heliophysics, or astrophysics, where feasible launch windows occur more frequently—and the large budget increases that result when a planetary mission such as InSIGHT misses its planned launch window. The next launch window is 26 months from now (May 2018), and a plan has been worked out with the Centre National d’Etudes Spatiales (CNES), the French space agency providing the Seismic Experiment for Interior Structure (SEIS) instrument, to determine and address the root cause of the leakage occurring in SEIS and have the instrument ready to marry up with the spacecraft when the latter comes out of storage and proceeds through normal assembly, test, and launch operations (ATLO). The additional funding needed to cover the delay of InSIGHT will come from elsewhere in the PSD

budget and will not endanger selections from the 2014 round of Discovery Program proposals.

The five 2014 Discovery selections are currently in their Phase A studies, which will be completed this summer. After evaluation of the studies, there will be a down-select to at least one project from the five. The phasing and costing done as part of the Phase A studies will determine whether more than one candidate can be selected.

Speaking on behalf of the Small Bodies Assessment Group (SBAG), Dr. Chabot said that the SBAG strongly supports the Decadal Survey's recommendation for five Discovery-class missions/projects per decade and supports anything that PSD can do to achieve that cadence. Dr. Green replied that the loss of 23% of PSD funding in FY 2012-2013 slowed everything down, and the programs are still living through the bottom part of the resulting "bathtub" in activity level. However, that low period is ending now, and PSD will be launching three missions in the next five years: the Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) mission, scheduled to launch in September 2016; InSIGHT, rescheduled for May 2018; and Mars 2020 [planned launch in 2020]. With the budgets and even the projections for out-years in a healthier state, PSD will be able to move forward, Dr. Green said, and look for a way to get back on track [with the Decadal Survey cadence].

New Frontiers and Addition of an Ocean Worlds Theme to the New Frontiers AO

Turning next to the New Frontiers program, Dr. Green reviewed the status of the three New Frontiers missions. New Horizons completed its successful Pluto flyby and has been targeted to another Kuiper Belt object. Approval for an extended mission will come from the Senior Review after the New Horizons team submits its proposal. Senior Review proposals are due in April, and Dr. Green expects that decisions on extended missions will be made by July. The extended mission phase for New Horizons would start on October 1, 2016. The second New Frontiers mission, Juno, (a Jupiter polar orbiter mission) will arrive at Jupiter on July 4, 2016, and is very healthy. The third New Frontiers mission, OSIRIS-Rex, is an asteroid sample return mission with a launch window opening on September 8, 2016. Dr. Green described its implementation phase as "doing wonderfully well." He cited it as being on track to come in under budget, as have several other recent missions.

To set the context for discussing a proposed expansion of mission themes for the fourth New Frontiers Announcement of Opportunity (AO), Dr. Green began with two National Research Council (NRC) reports requested by NASA: the 2008 report titled *Opening New Frontiers in Space* (commonly called the NOSSE report)² and the most recent Planetary Science Decadal Survey, *Vision and Voyages for Planetary Science in the Decade 2013-2022*, published in 2011. The NOSSE report was in response to NASA's request in 2007 to the NRC "to provide criteria and guiding principles to NASA for determining the list of candidate missions" for the New Frontiers program, which NASA had established in 2002. Dr. Green noted that, in requesting the NOSSE study, NASA recognized that the New Frontiers program was both a Principal Investigator (PI) led program and a strategic program, to be directed toward NASA's strategic

² NOSSE is an acronym derived from the formal name of the NRC-appointed study committee, the Committee on New Opportunities in Solar System Exploration.

objectives for solar system exploration. He cited and discussed several specific passages from the NOSSE report, including the following:

... in addition to the eight identified missions [identified in Recommendation 2 of the report], the committee believes that NASA should offer an additional option for other missions in the same size class that can acquire compelling information answering high-priority science questions from the decadal survey. The committee believes that this approach not only will provide an opening for innovation but also might enable the applicant pool for future missions to grow.

(NOSSE report, p. 4)

... the committee concluded that the mission options for the next announcement of opportunity cannot be drawn strictly from the decadal survey but rather should be interpreted in light of scientific discoveries made since the decadal survey was conducted in 2002....

(NOSSE report, p. 4)

Recommendation 3: NASA should consider mission options outside the three remaining and five additional medium-size missions described in the decadal survey that are spurred by major scientific and technological developments made since the decadal survey. As with any New Frontiers mission, these proposals must offer the potential to dramatically advance fundamental scientific goals of the decadal survey and should accomplish scientific investigations well beyond the scope of the smaller Discovery Program....

(NOSSE report, p. 5)

...Finally, the committee notes that the New Frontiers Program is intended to be both strategic—based on the science goals established in the decadal survey—and adaptable to new discoveries....

(NOSSE report, p. 5)

After reading excerpts from the NOSSE report, Dr. Green emphasized that adding things to New Frontiers does require community input, and providing that input is a role he sees for the PSS. He then discussed the importance of Ocean Worlds to the goals, objectives, and important questions detailed in Chapter 8, “Satellites: Active Worlds and Extreme Environments,” of the 2011 Decadal Survey. He then reviewed statements in the Decadal Survey indicating how its implementation should take into account new discoveries or other external circumstances that “dictate that change in strategy is needed.” With respect to new discoveries (since the Decadal Survey) that support a “science case” for an Ocean Worlds theme, Dr. Green reviewed key science findings from Cassini’s 56 flybys of Titan and 12 flybys of Enceladus, particularly the discoveries about the ocean and hydrothermal vents on Enceladus that came after the final drafting work on the Decadal Survey in late 2010 and the seasonal rains that transform the surface of Titan.

Dr. Green then turned to the congressional interest in Ocean Worlds exploration, particularly the language in House Report 114-130 (page 59) that gives NASA specific direction for use of the

\$226 million in funding for outer planets science:

Many of NASA's most exciting discoveries in recent years have been made during the robotic exploration of the outer planets. The Cassini mission has discovered vast oceans of liquid hydrocarbons on Saturn's moon Titan and a submerged salt water sea on Saturn's moon Enceladus.

The Committee directs NASA to create an Ocean World Exploration Program whose primary goal is to discover extant life on another world using a mix of Discovery, New Frontiers and flagship class missions consistent with the recommendations of current and future Planetary Decadal surveys.

This direction, in the context set by the NOSSE report and the 2011 Decadal Survey, Dr. Green said, is consistent with PSD's community announcement, issued in January 2016, of intent to add an Ocean Worlds mission theme to the fourth New Frontiers AO, with Titan and/or Enceladus as the specified target bodies for that theme. This would become a sixth mission theme, added to the five mission themes established by the 2011 Decadal Survey: Comet Surface Sample Return, Lunar South Pole-Aitken Basin Sample Return, Saturn Probe, Trojan Tour and Rendezvous, and Venus In Situ Explorer. Dr. Green also reviewed some other key elements from the community announcement, including the caveat that NASA has not yet approved issuance of the formal New Frontiers AO, which is currently scheduled for release in January 2017 (a draft version is planned for release by the end of September 2016).

Dr. Lori Glaze asked how the science objectives for the Ocean Worlds mission targets would be defined, to make that theme comparable to the themes from the Decadal Survey, each of which already has a defined set of science objectives, established through the Decadal Survey process, that have to be addressed by any New Frontiers proposal. She acknowledged that the OPAG has set up a group to work on science objectives for the Ocean Worlds mission targets but asked how those objectives would be vetted by the community, as the other science objectives have been. Dr. Green agreed with her that the science objectives for the Ocean Worlds targets need to be put on the same footing as the objectives for the other New Frontiers themes. (*Science objectives for Enceladus and Titan were described in the second New Frontiers community announcement of 4/25/16*) He suggested that the necessary vetting could occur through consideration by CAPS of the input from the OPAG group.

Dr. Luhmann questioned the scientific feasibility of the House Report language specifying that the primary goal of an Ocean Worlds program be "to discover extant life," given the difficulty of even establishing that conditions hospitable to life exist on one of the target bodies. She expressed concern about having expectations set too high and suggested that interactions are needed to ensure that Congress and others supporting the program understand the scientific challenges in meeting the direction to NASA. Dr. Green replied that a lot of discussion in the exobiology community is on the issue of how to find and measure life. He said the three attributes that are accepted as defining life are that: (1) it ingests material and metabolizes it to extract energy, (2) it has to be able to reproduce, and (3) it evolves. But since he knew of no instrument one could actually build (now) to make decisive measurements for assessing those three defining attributes while sitting on a remote body, one would have to consider other attributes commonly associated with life as we know it that could be sought for and measured by mission instruments, attributes such as complex organic substances, chirality, or DNA and RNA [molecular basis for a genetic code]. So a complicated set of measurements are needed, he said, and we do not yet have instruments that can do all of them. This situation, Dr. Green continued, has generated discussion

on where NASA should be investing in instrument technology to be able to move forward. One approach being pursued is to organize a set of scientific conferences for the August 2016 time frame that will include relevant scientific communities such as the oceanography community, to find out how they look for and measure life in the ocean, and what kinds of instruments are available. In addition, NASA has asked the NRC to report on issues in life detection, and that report is planned for release in Fall 2016.

With respect to the related scientific objectives for the Europa Lander mission, Dr. Green said that a Science Definition Team (SDT) has been established to determine the kinds of scientific investigations that need to be done to meet the objectives of that mission. Based on that team's report, which will come out in several months, PSS will formulate a call for instrument proposals for the Europa Lander mission. The current plan is to do an initial overselection of instrument proposals, as has been done for other missions, and then do a down-select as the maturity, measurement capabilities, and development challenges of the candidate instruments are more fully assessed. The Europa Flyby mission is moving ahead on its own (independent of the Lander mission) and is well into Phase A formulation, so PSD is working to bring the Lander mission along and catch up with the Flyby mission. The Europa Lander mission, Dr. Green said, has major connections with the Ocean Worlds activity. He anticipates releasing an instrument call for the Europa Lander during Fiscal 2016. *(An advance notice was released 4/25/16 that a call for lander instrument technology development will come in May)*

Dr. Harry (Hap) Mcsween, participating by teleconference, asked if planetary protection constraints currently preclude a sample return, as part of the Ocean Worlds exploration program, from, for example, the Enceladus plume. He suggested that a sample return of that sort would be a good way to approach the search for extant life. Before such proposals could be developed, he added, the investigators would need to know the planetary protection requirements, so coordination with [the NASA Office of Planetary Protection and the Planetary Protection Subcommittee of the NAC Science Committee] would be necessary. Dr. Green agreed and described what PSD is doing with regard to planetary protection policies and procedures. The NRC has already published a report on planetary protection requirements for the outer planetary bodies.³ He is working with the NASA Planetary Protection Officer on a new request to the NRC for a review of tools, techniques, and capabilities available to ensure planetary protection particularly in areas where water is present and for potentially returning samples that may contain life. We are now at the point, Dr. Green said, where NASA needs these capabilities for planetary protection, and catch-up work is needed.

Dr. Lisa Pratt commented that planetary protection issues would be an important part of the report from the recent meeting of the Mars Exploration Program Analysis Group (MEPAG). She added that life is only difficult to detect when there isn't much of it; for example, there was no doubt when the hydrothermal vents off the Galapagos Islands were first explored that the scientists were seeing life there.

Returning to the planning for the NF 4 AO and speaking for the small bodies community, Dr. Chabot emphasized that her community supports restricting the set of mission themes in NF 4 to

³ The report *Assessment of Planetary Protection Requirements for Spacecraft Missions to Icy Solar System Bodies* was published in 2012 and is available from the National Academies Press at <http://www.nap.edu/catalog/13401/assessment-of-planetary-protection-requirements-for-spacecraft-missions-to-icy-solar-system-bodies>.

those developed through the Decadal Survey process. She encouraged the PSS to weigh in on the issue of the NF 4 themes in its findings from this meeting.

Dr. McEwen (new OPAG chair) said that OPAG is currently looking into long-term objectives for an Ocean Worlds program but is not attempting to address NF 4. So the question of the science objectives for an Ocean Worlds mission theme in NF 4 does need to be addressed. Dr. Green agreed and said that PSD is in the process of addressing it, but the plan is not ready to be presented yet.

Summing up his presentation on New Frontiers and the new Ocean Worlds theme, Dr. Green said that PSD is seeking community input on what it has proposed. PSD now has an opportunity to add to the program without taking off anything already there, in the context of a competition that any proposal for the new theme would have to win against all other proposals. There is no preconception that a proposal for one theme would be selected over another in that competition; the customary scientific, readiness, and cost-cap criteria will be applied. The NOSSE Report said that New Frontiers should be adaptable to new discoveries, and the most recent Decadal Survey said that “A decadal survey should not be blindly followed if external circumstances dictate that a change in strategy is needed.”⁴ A compelling science case exists for undertaking an exploration missions to Enceladus and Titan, and NASA has to respond to the Congressional direction in the House Report on the FY 2016 appropriation for planetary science. In that context, the next steps for PSD are to (1) present the PSD decisions on NF 4 and related activities to the PSS at this meeting, (2) present the NF 4 decision and rationale to CAPS at its next meeting (March 29-31, 2016) for feedback, and (3) request community comment via the draft AO process prior to the final NF 4 AO.

Dr. Christopher House commented that he thought the astrobiology community would be excited by the addition of Enceladus and Titan to the NF 4 themes. The planetary protection requirements will be a daunting challenge but will also excite the community. He asked if there would be two different sets of Ocean Worlds science objectives, one for each target body, or would they be generic objectives applicable to either target? Dr. Green said that the answer to that question has not been decided yet, but he would anticipate that looking for life on Titan would be very different from looking for life on Enceladus. He imagined that some objectives might be similar (for the two targets) and some would be different. *(4/25/16 Yesterday's announcement has two different sets of objectives)*

Dr. Neal expressed surprise about the reliance on the NOSSE report, since he sees that report as coming in the context of the prior Decadal Survey and being succeeded by the 2011 Decadal Survey. He suggested that a similar midterm check on the status and goals of the Decadal Survey would be a great idea. There was discussion among Dr. Neal and several other meeting participants on whether the NOSSE report added New Frontiers missions to those established by the earlier Decadal Survey and whether the NOSSE comments on adding to the New Frontiers mission list were still relevant in light of the subsequent Decadal Survey. Dr. Neal said, speaking as chair of the Lunar Exploration Analysis Group (LEAG), that the prevailing perception in the lunar science community is that, given the congressional direction for an Ocean Worlds program, the Ocean Worlds theme would have priority in the NF 4 competition. Everything else will be at a disadvantage because NASA now has a congressional mandate to do Ocean Worlds. Given that perception, members of his community see little value in putting the effort into developing a proposal for NF 4. He asked if the NOSSE report would be superseded by a new midterm review.

⁴ The quote is from *Vision and Voyages for Planetary Science in the Decade 2013-2022*, p. 314.

Dr. Green replied that any perception that the Ocean Worlds theme would have priority over the other five “is unfortunate.” He added that the charge to the NRC study committee for a midterm review would include the question of how NASA and PSD should deal with discoveries that occur after the latest Decadal Survey is finalized. There was further discussion among Dr. Neal, Dr. Green, and others on whether the Ocean Worlds theme would have priority in the NF 4 competition or would be at a relative disadvantage in the competition because of the relative immaturity of potential mission proposals. Several PSS members commented that their communities shared the perception reported by Dr. Neal that the Ocean Worlds theme would be favored in the NF 4 competition. Differing views were presented and debated on whether the proposed approach for adding a new mission theme to NF 4 was or was not consistent with adhering to the Decadal Survey’s community-driven process for planetary science program planning, whether addition of the Ocean Worlds theme in NF 5 would be a better approach, and whether the NOSSE report was an appropriate rationale for the decision to add the Ocean Worlds theme to NF 4. PSS members and other participants also presented alternatives for responding constructively to the congressional direction other than adding a new theme to NF 4.

Europa Mission, Planetary Defense Program, and NRC Study Timeline

Formulation for the Europa Multi-Flyby Mission is proceeding well, Dr. Green said, with concept studies continuing on several approaches for a Lander component. The SDT will address what science will be done from a platform sitting on the surface.

Within the past 6 months, NASA established the Planetary Defense Coordination Office (PDCO) within the PSD. The PDCO is responsible for oversight of potentially hazardous objects (PHOs), which includes ensuring early detection, characterizing PHOs of size large enough to affect Earth’s surface, providing warning of potential impact effects if a PHO is not deflected or mitigated, and providing timely and accurate communications about PHOs and any potential impact. Other PDCO responsibilities are to lead research into technologies and techniques for potential asteroid deflection and impact mitigation (the joint AIDA/DART mission with ESA is an example) and to take the lead coordination role in Federal planning for response to an actual impact threat (by providing, for example, planetary science and deep space mission expertise for a Federal Emergency Response Team).

Dr. Green agreed with Dr. Amy Mainzer that the 2010 NRC study, *Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies*,⁵ served as the community’s decadal-process guidance in the area of PHO detection and mitigation. He noted that NASA and PSD are using input from other advisory structures, such as the Near-Earth Object (NEO) Task Group, which reported directly to the NASA Administrator

Next, Dr. Green discussed the timeline of NRC Space Studies Board studies that will provide community-based input to PSD. The first Planetary Decadal Survey covered the decade 2002-2012, and the second covers the decade from 2013 through 2022. He expects the third Planetary Decadal Survey (covering 2023 through 2032) to be tasked to the NRC before October 2019, with the final report delivered to NASA in the first quarter of 2022. In the interim, studies already in progress include (1) an Extended Missions review, tasked April 30, 2015, and due to NASA in September 2016; (2) a review of the restructured R&A program, tasked in August 2015 and due

⁵ This report is available from the National Academies Press at <http://www.nap.edu/catalog/12842/defending-planet-earth-near-earth-object-surveys-and-hazard-mitigation>.

to NASA in December 2016; and (3) a study of the role that large strategic science missions play in a balanced program, tasked in March 2016 with delivery to NASA anticipated in August 2017. All three of these reports, according to Dr. Green, will be important as inputs to the midterm evaluation of PSD status and progress with respect to the decadal survey guidance. He expects the midterm evaluation study to be tasked to the NRC by September 2016, with anticipated delivery of the final report in December 2017. In addition to the midterm evaluation report, there will be several mission-focused studies that will provide input to the third Planetary Decadal Survey.

Response to PSS Findings from the October 2015 Meeting

Dr. Green said that Dr. James Watzin's presentation on the Mars Exploration Program (MEP) would respond to the PSS request for details at this meeting about the anticipated funding wedge and management plan for the currently envisioned set of highly collaborative missions (across NASA Directorates)—including the Mars 2022 Orbiter—on the path to sending humans to Mars.

PSD concurred with the PSS finding that applauded and encouraged continued support of the lines of PI-led cost-capped missions (the Discovery and New Frontiers programs). Dr. Green said that PSD would also like to re-establish the 24-month cadence for Discovery AOs recommended by the Planetary Decadal Survey and will try to do so.

The third finding from the October 2015 meeting renewed the PSS request for selection statistics and other details needed to assess the reorganized R&A program, particularly data related to the proposal review, selection, and funding processes. Dr. Green said that some of the information requested is already publicly available on the R&A program website and is reported periodically. PSD staff have been developing some tools to gather the kinds of statistics and data requested by the PSS. Some results from applying these tools for the year before the restructuring and for other data requested by the PSS are included in the R&A program briefing for this meeting (see below). He also noted that the NRC has a task from NASA to assess the reorganization, and the report will be publicly available when completed.

PSD also concurred with the part of the R&A program assessment finding encouraging a regular dialogue with the planetary science community about the R&A program through venues such as "town hall" sessions at the Lunar and Planetary Science Conference (LPSC), meetings of the Division for Planetary Sciences (DPS) of the American Astronomical Society, and meetings of the American Geophysical Union (AGU). Dr. Green added that PSD is trying to be as open and transparent about the R&A program and processes as possible.

With respect to the finding on AG status and PSS support for continuing opportunities for the AGs to report to PSD leadership and participate in PSS meetings, Dr. Green said that PSD certainly concurs. PSD values the AGs and is doing everything it can to continue the AG structure.

R&A Program Status Update

Dr. Michael New gave the briefing, as Dr. Rall was serving as the Responsible Federal Officer (required by FACA) for this subcommittee meeting. A Research Opportunities in Space and Earth Sciences (ROSES) announcement for PSD R&A programs was released in February 2016, and Dr. New presented a list of the Step 1 and Step 2 due dates for the 16 R&A program titles in the announcement. Dr. Chabot asked whether a New Frontiers Data Analysis Program (DAP) was going to be included this year, as it was not on the list but data are now available from the New

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Horizons mission. Dr. New replied that a New Frontiers DAP is coming; it was not included in the February ROSES announcement because details of the program were not fully decided. He was not sure what the formal name of the DAP would be, but there will be a DAP line funded under New Frontiers for the Pluto data now and for the Jupiter data when it begins to arrive. An amendment to the ROSES 2016 announcement will be made for it.

Deadlines for Solar System Workings Program Proposals

Dr. New reviewed the timeline for due dates in the Solar System Workings (SSW) R&A program for FY 2015 and FY 2016. Although there were two Step 2 deadlines for SSW 2015 (Sept. 10, 2015, and February 25, 2015), there will be just one Step 2 deadline for SSW 2016 (Feb. 23, 2017). Having a two Step 2 deadlines for SSW 2015 was an experiment to see if two deadlines would ease the calendar crunch for both proposers in the community and NASA staff. The February time frame for the SSW Step 2 deadline is much less congested with other R&A proposal deadlines. Dr. Chabot commented that some early-career investigators who attended the SBAG meeting where the new SSW deadlines were presented had said that the lack of a Step 2 deadline before February 2016 represented a hardship in terms of competing for a funding opportunity within a postdoctoral fellowship year. Dr. New responded that early-career investigators in that situation should not focus narrowly on the SSW program but should look into other PSD R&A programs with earlier deadlines, to which they could propose. There was further discussion between Dr. Chabot and Dr. New about the relative size of SSW, the overlap with other DAPs, and the past history of proposal due dates in specific R&A programs. Dr. Luhmann suggested that there seemed to be a larger issue involved: the reliance on R&A programs to provide funding for academic research careers and how investigators can manage that within the framework of what the planetary science programs at NASA provide. She suggested that this larger issue be a topic for deeper exploration at another PSS meeting.

Statistics on R&A Submissions and Selection Rates

Dr. New next presented data on the numbers of Step 2 proposals submitted for all the PSD R&A programs solicited in ROSES 2014 and 2015 and the percentage change between the two years. The number of proposals increased in some programs (for instance, Exobiology increased 24% from 144 proposals in 2014 to 190 in 2015) and decreased in others (SSW decreased 18% from 384 to 315 proposals). Dr. New said there was no clear pattern, although the changes in some programs were clearly related to changes in the amount of data coming from a given operational mission. Dr. Amy Mainzer asked if PSD had data on how many of the proposals came from first-time applicants to NASA R&A programs. Dr. New said that data were not yet available on that, but gathering data on career stage of applicants has been discussed. He and Dr. Mainzer discussed how information on the date of applicants' latest degree might be gathered. In response to a question, Dr. New said that the only R&A programs that are cross-divisional (supported by other divisions as well as PSD) are the Extrasolar Research Program (XRP) and Habitable Worlds (HW). The proposal numbers for these programs in the table he presented are just the proposals directed to PSD.

Dr. New discussed statistics from the ROSES 2014 R&A selections showing the percentage of proposals that were selected for funding by their merit score. The statistics were for all core R&A programs and all DAPs. While 100% of proposals rated Excellent were selected, only 84% of

proposals rated Excellent/Very Good and 37% rated Very Good were selected. Overall, the selection rate was 21% (percentage of total submitted proposals that were funded). When the corresponding data for ROSES 2015 are available, the selection metric graphic will be updated. Dr. New and Dr. Neal discussed the general perception in the community of R&A applicants that in the past, proposals rated at least Very Good had a high chance of being selected and the reasons why some proposals rated Excellent/Very Good may not have been selected. (Dr. New noted that corresponding data were not available for ROSES prior to 2015.) The constraining factors include the total R&A budget and the average cost of the highest-rated proposals. In response to a question from Dr. Neal, Dr. Green said that the \$10 million increase in R&A funding would apply to ROSES 2017, and Dr. New added that the average amount requested in an R&A proposal, across all PSD programs, is about \$550,000.

Dr. Rall noted that the time required this year to get budgeted funds released for ROSES awards was particularly lengthy, and funds were only released in the past several weeks. This led into the next part of Dr. New's briefing, which diagrammed the sequence of steps in NASA's budget/funding process as it connects with the ROSES selection and award sequence (the "Where's My Money" flowchart). Dr. New stressed the requirement that NASA submit an Operational Plan to Congress on how it intends to spend appropriated funds, but then NASA must wait for Congressional debate, revisions of the Operational Plan, and eventual Congressional approval, before selection decisions can be announced. This year, he said, the Operational Plan was not approved until about 2 weeks before this PSS meeting. He then explained how the remaining steps after the selection decision can further delay the actual receipt of the grant award by the PI's institution.

PSD-Funded Facilities Open to the User Community: The Facilities RFI and LPSC Special Session

PSD-Funded Facilities, which support the needs of the R&A community were the next topic of discussion. The five major facilities in this category are the Planetary Aeolian Lab at NASA Ames Research Center, the Reflectance Experiment Lab at Brown University, the Glenn Extreme Environments Rig at NASA Glenn Research Center, the Ames Vertical Gun Range at NASA Ames Research Center, and the NASA Regional Planetary Image Facility (RPIF) Network (a distributed resource). To determine whether these facilities still are supporting the needs of the R&A community, PSD is conducting a Community Needs Assessment of these user-accessible PSD-Funded Facilities. PSD first asked the currently supported facilities (except the RPIF Network) to give progress reports in the form of presentations at NASA Headquarter (HQ) to a panel composed of community members and users. (The big five facilities reported between October 12 and November 16, 2015.) The panel prepared a summary of lessons learned for PSD management. To gauge community interest and needs, PSD released a Request for Information (RFI)⁶ on January 28, 2016, responses to which are due back to Doris Daou at NASA by April

⁶ The full text of the RFI is available on the NASA website at <http://science.nasa.gov/researchers/sara/grant-solicitations/nasa-request-information-assessing-planetary-science-communitys-use-planetary-science-division-facilities/>. It is also available on the Lunar Planetary Institute (LPI) website at <http://www.lpi.usra.edu/psd-facilities/RFI/>. The LPI webpage also has information about the LPSC Special Session on PSD-Funded Facilities and a list of smaller PSD-funded

30, 2016. PSD will also host a session on PSD-Funded Facilities at the March 2016 LPSC. The plan for the session includes five invited talks (from the current big five facilities), 13 oral presentations, and 49 posters. The aim for both the RFI and the LPSC session is for PSD to gather feedback from the R&A user community on the kinds of PSD-Funded Facilities it needs. The planned next step is to release a Cooperative Agreement Notice (CAN), probably near the end of calendar year 2016, through which interested parties can propose their facilities for PSD funding support as a service facility open to the R&A user community. Evaluation criteria will be included in the CAN and will incorporate information about user needs gathered via the RFI and the LPSC special session. Currently funded PSD-supported facilities whose contracts (or grants, in the case of the RPIF Network) are nearing completion are expected to reapply, as can anyone else with relevant facilities.

In response to a question from Dr. Mihaly Horanyi about access to PSD-Funded Facilities, Dr. New said that at present a PSD-Funded Facility is required to provide access time for anyone who receives funding through a PSD R&A program. He thought that, under the new cooperative agreement mechanism, the terms of access would probably be left to the applicant to propose, depending on whether the funding requested would cover all operating cost (with no fee to users) or just a portion of operating cost (with a user fee to cover the remainder). Generally, he said, CANs try to be open to whatever creative solutions an applicant may propose.

Dr. Luhmann asked if PSD was considering reducing the number of, or turning over, the facilities currently receiving PSD support. Dr. New replied that the objective is to try to ensure that the facilities supported by PSD this way are in fact meeting the community's needs. If the current facilities are meeting those needs, that would be good; if the answer to the needs assessment is that the facilities meet some of the needs but there are other needs not being met, then the CAN mechanism would be used to try to fill those gaps. In response to a question from Dr. Chabot, Dr. New explained that the review of the current facilities in 2015 was intended to get them thinking about how to better meet current community needs before they have to respond to the CAN. He agreed with her that there seemed to be a lot of community interest in proposing facilities as additions to the set of PSD-Funded Facilities and he described the sources of funding in the past for the big five facilities, adding that the number and support level for PSD-Funded Facilities was not yet decided and would depend on the needs assessment process and the outcome from the CAN proposal evaluations. By the time the CAN is released, there will be a budgeted amount for cooperative agreements, but the budget has not been decided yet. Dr. New said it would probably be at least the amount of the current budget for PSD-funded Facilities.

Dr. Larry Nittler said that, based on email traffic, there is a great deal of angst in the R&A community about the Facilities RFI and the LPSC special session. The concern seems to be that PSD support for laboratory facilities generally is moving toward requiring them to be open to other users (beyond a PI's own group and collaborators) to receive any PSD funding. Every planetary materials laboratory in the country, Dr. Nittler continued, submitted an abstract for the LPSC special session because of panic that their laboratory/equipment support from PSD would otherwise be lost. Dr. New replied that, to his knowledge, PSD had no intention to "kill off"

facilities (see the SARA Page for Planetary R&A Facilities at <http://www.lpi.usra.edu/psd-facilities/SARA/>).

individual investigator laboratories or stop funding for expensive but essential equipment. Rather, this activity is intended to be a needs-based rational re-assessment of what facilities PSD should support to provide access for the wider user community to specialized facilities, rather than relying on past history and “folklore” to determine what “community facilities” are supported. In answer to another question, Dr. New said that a facility or lab that was proposed but not selected under the CAN to be a PSD-Funded Facility could still apply for other funding as part of a regular R&A program proposal as in the past. “We want to find a method for replenishing that list [of NASA-funded facilities in Appendix C.1 of every ROSES announcement],” Dr. New said. He also agreed with a comment from Dr. Harry McSween that advances in technology and techniques are more likely to come from investigators’ dedicated laboratories rather than from the PSD-Funded Facilities that primarily provide services to a broader user community. He repeated the point that PSD’s intention is not to erode support for individual laboratories by replacing them with PSD-Funded Facilities open to the community.

Dr. Chabot asked if there had been any further thought within PSD on a related topic, previously discussed at PSS meetings, of the scarcity of resources to support expensive equipment and laboratories being used for planetary science including R&A projects. Dr. New replied that the problem is recognized and continues to be discussed, but PSD does not have a proposed solution in hand.

In response to a question from Dr. Luhmann, Dr. New said that the recent Planetary Data System (PDS) RFI was the first step in a process to develop a community-led, decadal-scale roadmap for the PDS. Dr. Ralph McNutt, the PDS Chief Scientist, will be leading the roadmap activity. A call for self-nominations to serve on the roadmapping team will be announced soon. The information gathered through the RFI will be incorporated in the roadmap activity. In response to a question about the facilities in the RPIF Network, Dr. New said that they have also been asked to provide progress reports to PSD and are expected to apply for renewal of support through the CAN as their grants expire. He listed the questions posed to the RPIF Network sites to gauge their contribution in supporting the R&A community as well as for education and public outreach.

Other R&A Topics

Dr. New presented budget amounts for the individual funding lines in the FY 2016 PSD research budget and discussed the component research and data analysis programs covered by each funding line. Although the line for Europa Technology is not fully decided yet (estimated at \$25 million), the total for all lines is about \$214.1 million. The largest line is \$154 million for Planetary R&A, followed by \$20.9 million for NEO Observations, \$11.4 million for Discovery Research, \$9.4 million for Mars R&A, and \$8.4 million for Outer Planets Research.

The objective of the newly tasked National Academies study of the restructured PSD R&A programs is to examine the program elements as they currently exist following restructuring, for their consistence with past NRC advice. Specifically, the study committee is tasked to address two questions: (1) Are the PSD R&A program elements appropriately linked to, and do they encompass the range and scope of activities needed to support, the NASA Strategic Objective for Planetary Science and the Planetary Science Division Science Goals, as articulated in the 2014 NASA Science Plan? (2) Are the PSD R&A program elements appropriately structured to develop the broad base of knowledge and broad range of activities needed both to enable new

spaceflight missions and to interpret and maximize the scientific return from existing missions?

Dr. New highlighted several procedural points about ROSES 2016 that applicants to PSD programs need to keep in mind. An important budget change is that all salaries (not just NASA civil servants, as in the past) must be included in the cover page budget tables, which will be automatically redacted and hidden from reviewers. Full-time equivalents (FTEs) do need to be included in the work effort table, but do not include dollar values of salaries (or overhead) in the budget justification section. All applicants should read Appendix C.1 carefully, as it explains general requirements that apply to all program elements. The two-page Data Management Plan (DMP) is not included in the 15-page limit for a proposal, and there is a new PSD-specific frequently asked questions (FAQ) page for DMPs. Some R&A programs in PSD are now evaluating, or moving toward evaluating, DMPs as part of the proposal merit evaluation.

In response to a question, Dr. New said that the R&A program elements will differ for a while in whether they include the DMP in the merit evaluation—as they differ in other factors such as programmatic relevance—but at some time in the future all program elements will be including the DMP in the merit evaluation. There will be a session at the LPSC on what is expected in a DMP. The driver for this change on DMPs is that the Office of Science and Technology Policy (OSTP) is requiring that researchers funded by Federal agencies make their data available to the public. The NASA Office of the Chief Scientist is developing a website that will include tutorials on the requirements and the process. In response to another question, Dr. New said that it will be acceptable to state in a DMP that the project proposed will not be generating any data that needs to be archived, and also state why, if this is true for the research being proposed. An acceptable solution may be to state that all data will be incorporated in the supplementary material accompanying a research publication.

Dr. New presented results from analysis of the keyword field for Target Object in the Raptor Information System. The analysis included competed ROSES programs, mission DAPs, and Participating Scientist programs from FY 2011 through 2015 but excluded proposals for the NASA Astrobiology Institute (NAI) and the Solar System Exploration Research Virtual Institute (SSERVI). Two caveats are that NASA Program Officers did not always include keyword entries in their Raptor entries and different Program Officers used some keywords differently. In one chart, Target Object keywords were grouped into Object of Study categories such as Mars System (Mars and its moons), Earth and Early Earth, Outer Planets, Small Bodies, Mercury, Venus, Moon, and Other Targets. The chart showed results for each fiscal year, specifying both the dollar amounts in each Object of Study category and indicating the fraction of the total for that category (fraction of a bar with entire bar equal to 100% of R&A funding for the year). Subsequent charts broke out the Small Bodies, Outer Planets, and Other Targets categories into subcategories.

Dr. Luhmann noted that these statistics addressed the PSS request for information on programmatic balance across the R&A programs. Dr. Green commented that the effort to compile these statistics began several years ago, and he complimented the staff for the additional effort required to enable the analysis. PSS members asked questions about program trends over time, and members and staff discussed how certain changes in funding level from year to year might reflect new mission data becoming available.

Dr. Nittler commented that a finding from the PSS meeting had asked for more data and

information on the restructuring of the R&A programs. He suggested that part of the response to that request was that the NRC report on the restructuring precluded providing more detailed data on the restructuring to the community. Dr Green replied that his comment about the NRC review was not meant to imply a decision against providing information to the broader community, just that PSD would be doing an extensive review of the restructuring. He then described how the information in this briefing had covered some portions of what the PSS had requested, while other portions (e.g., on individual selections in particular R&A program elements) were in R&A selection announcements posted on the PSD website or were considered by PSD to be information more personal to the individual applicant (such as merit scores on individual proposals). The composite statistics presented during the briefing reflect analysis of about a thousand proposals in each fiscal year analyzed.

Dr. Timothy McCoy asked if the analyses presented in the briefing were the level and type of information that would be provided to the NRC study committee. Dr. Green replied that whatever the NRC requested (in terms of information and data) would be provided if feasible. He added that, as information is developed for and presented to CAPS [and the R&A study committee], the same information will be made available to the community. Dr. McCoy suggested that the selection metrics graphics for the five core R&A program elements, as well as for the entire R&A program, would be important for the PSS to see, especially as the analyses for FY 2016 are completed. Dr. Green said that the planetary science program, including the R&A program, will be shared with the community at the NASA Night portion of the upcoming LPSC.

Mars Exploration Program and Mars 2020 Update

Dr. James Watzin, MEP Director, said that overall, the state of the MEP is good. All of the operational assets remain healthy and productive. MAVEN successfully completed its prime science mission and is now continuing investigations in an extended mission, pending Senior Review at the next review cycle. Odyssey, the oldest MEP asset at Mars, remains healthy and continues to produce thermal imagery and provide data relay services. The Mars Reconnaissance Orbiter (MRO) continues to produce reconnaissance imaging and mineralogical mapping, which support science investigations, rover operations, and exploration of potential human landing sites. The Mars Exploration Rover (MER) Opportunity is still providing ground truth data and recently scaled 30-degree slopes on Knudsen Ridge to investigate pristine red rock zones of scientific interest. The other MER, Curiosity, continues to explore Gale crater, generating important insights into Martian chemistry, which will be presented at the science meeting in April. The international collaboration mission, Mars Express, continues to produce scientific data, including information from the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) deep radar sounder.

Mars 2020 Status

Development work for the Mars 2020 rover mission (M2020) remains on track and is proceeding well, with the Preliminary Design Review (PDR) successfully completed in February. (Two months of build-up PDRs were completed successfully in preparation for this system-level PDR.) Some of the hardware based on heritage designs from earlier rover missions has already been received. Dr. Watzin said the use of the heritage designs is paying off well; cost performance on delivery of heritage hardware continues to run below plan. Development of the sampling system,

a major new development for M2020, has been analyzed into component subsystems, which have been assigned to various labs for development. Dr. Watzin reviewed challenges and development status of the major mission elements for M2020, including the launch element; cruise/approach element; and the entry, descent, and landing element, as well as the rover and surface mission element. An Operations Team has been assembled early in development to work on expediting rover operations relative to Mars Science Laboratory (MSL) performance. Overall, M2020 is progressing on schedule and within its cost target.

In response to questions from Dr. Neal, Dr. Watzin said that international contributions to M2020 are on track; he described the redesign of the rover wheels to avoid the wheel degradation experienced by MSL.

MEP International Commitments and Financial Overview

International commitments made by MEP are being met. TGO is scheduled for launch (*Since the MARCH PSS meeting, the spacecraft launched is doing well, instrument checkout complete*) by ESA the week of March 14 with two Electra payloads from MEP on board, which will boost the relay assets available to Mars missions. The Mars Organic Molecule Analyzer (MOMA) instrument is proceeding in development for ESA's ExoMars rover mission. The gas chromatograph portion of MOMA is still struggling, but the NASA-contributed laser for MOMA is on track and has been performing well in testing. Delivery from the Germans of the spacecraft flight laser has fallen further behind schedule. The delivery date for the integrated instrument package will be affected.

MEP is also doing well on the financial side, Dr. Watzin reported. Funding for FY 2016 was adequate for all planned MEP activities, so it was not necessary to phase out some still-functioning operational assets that had completed their primary missions. The President's FY 2017 Budget Request is sufficient to support all of MEP's planned activities for developmental and operational missions, plus some support for work on future mission planning. For M2020, cost estimates for new developments, particularly the instrument payload and the Sampling and Caching System (SCS), include acceptable financial and schedule margins to support a 2020 launch.

Response to PSS Findings on MEP

Dr. Watzin next responded to PSS findings from the October 2015 meeting related to MEP. The first finding had requested details on the anticipated funding wedge and management plan for the envisioned set of highly collaborative missions, requiring coordination across multiple NASA directorates, to meet the merged set of goals for planetary science, technology demonstration, and eventual human exploration.

Dr. Watzin's response was that, while the President's FY 2017 Budget Request was supportive of cross-directorate collaboration to prepare for NASA's Journey to Mars vision, that budget only provided funding (\$10 million) to SMD for early work on a future Mars orbiter focused on ensuring continuity of data relay capabilities for future Mars missions. MEP is moving forward on supporting the needs for data relay capability for both science investigations and communications infrastructure supporting all Mars missions. Owing to the potential for

substantial cost efficiency, formulation studies will consider enhancing the next Mars orbiter with scientific and exploration capabilities consistent with the approved mission budget. However, Dr. Watzin added, MEP is more focused this year on meeting the needs of MEP.

Planning for the Next Mars Orbiter

Dr Watzin then discussed the “big picture” for Mars exploration, leading eventually into preparing for future human explorers. The decade and a half of missions focused on the theme of “Follow the Water” is nearing an end, and the next several years will continue the theme of “Explore Habitability” and, with the ExoMars and M2020 rover missions, move into the theme of “Seek Signs of Life.” Looking ahead to the decade of the 2020s, Dr. Watzin cautioned that MEP has been operating successfully and with asset longevity exceeding prime mission goals, but the key operational infrastructure for telecommunications relay and basic orbital reconnaissance is aging, which places the decade of the 2020s at risk. From a strategic perspective, MEP also continues to have a focused priority, established by the 2012 Planetary Decadal Survey, to move forward on “elements of the Mars Sample Return Campaign.” The M2020 mission and payload are a first big step toward those elements, as M2020 includes characterization of a site and careful selection and documentation of a suite of samples acquired and encapsulated for future return to Earth.

In this context, the next element of MEP is to focus on the “next Mars orbiter.” The desired capabilities for the new orbiter include (1) renew and update the aging communications infrastructure, (2) provide continuity of high resolution imaging, (3) provide essential orbital support for sample return, (4) enable potential resource prospecting for future landing sites and (human) exploration planning, and (5) ensure continuity of relevant remote sensing (from orbit) both for scientific investigation and to support surface mission (rover) operational planning. Many examples exist, Watzin said, of architecturally flexible and adaptable spacecraft capable of supporting an orbiter mission with these objectives. Critical to providing adequate mission flexibility (i.e., modifying orbit without exhausting limited fuel supplies) is that the spacecraft needs to be adaptable to Solar Electric Propulsion (SEP). SEP would also enable the mission to use the lowest-cost launch vehicle while increasing mass delivery (into Mars orbit) capability and providing return-to-Earth capability (for sample return). Given that an orbiter arriving at Mars at the earliest opportunity (2023, based on planetary orbits of Earth and Mars) would be in Odyssey’s 22nd year of service and the 18th year of service for MRO, starting Phase A development in 2017 is essential. (Nominal launch date would be in latter part of FY 2022.) A Mission Concept Review is planned for Summer 2016. MEP is exploring partnerships for the mission in the international community and commercial partnerships this spring, and it will establish a baseline project architecture and an Objectives and Requirements Definition Team (ORDT) during Summer 2016. The detailed spacecraft studies and other elements of Phase A implementation are planned to begin in Fall 2016.

Questions and Discussion on MEP

Dr. McEwen suggested that with TGO about to launch, this would be a good time to begin establishing a Participating Scientist program for it. Dr. Watzin replied that MEP has been talking about and working on a Participating Scientist program for TGO, and he hopes to have something more fully structured to announce later this year. Dr. McEwen then asked if MEP has a policy

like that of the Discovery and New Frontiers programs, limiting the extent of international contribution for MEP missions. Dr. Watzin replied that to some extent MEP is a “different ballgame” in that each Mars mission is now also a strategic mission (unlike the competitive programs such as Discovery and New Frontiers). So MEP aims to have adequate control over how the mission is executed, in order to meet the mission’s strategic objectives. That tempers what the program would consider incorporating from others. Enhancements to a mission can be more relaxed about potential outside contributions.

Dr. McSween agreed that the new orbiter would appear to be the necessary relay for the ground elements for Mars Sample Return. He asked if there might be communications requirements related to sample return that might need to be considered now. Dr. Watzin answered that MEP future missions planning has been looking at concepts to implement the ground elements of a sample retrieval and return mission over the past year, including the communications support needed. Those needs will be incorporated in the communications specification for the orbiter. He thought that that aspect of planning for the orbiter was in good shape.

Dr. Pratt said there had been a lot of discussion at the recent MEPAG meeting about the complicated tradeoffs for the next orbiter that would come in in working with the human exploration side of NASA and in renewing infrastructure capabilities. There was concern for the objective of scientific investigation and the value of having competed scientific instruments included in the orbiter payload. Going back to the concerns raised by PSS in its October finding, Dr. Watzin said that MEP had been advocating a more fully integrated program at that time, but that direction was not supported in the President’s FY 2017 Budget Request, which focused more on MEP objectives in its path forward. So a priori, the orbiter is not now a heavily integrated program, although there are opportunities to address integrated needs, which are being explored. This shift in emphasis, he said, would serve the program well and make the orbiter mission more manageable.

Dr. Glaze asked about possible small-sats and rideshares on the M2020 mission and on the next orbiter spacecraft. Dr. Green began his reply by referring to the ROSES 2014 call for Small Innovative Missions for Planetary Exploration (SIMPLEx), from which PSD selected two proposals and invested in three others. PSD plans to use that approach again, but it is still in formulation and was not included in the ROSES 2016 call released in February. Because there is a supporting communications infrastructure at Mars, there may be an emphasis in the next ROSES call on CubeSats at Mars. A rideshare approach would be involved, Dr. Green said, because one needs a way to get CubeSats to Mars. PSD is looking into how a call of that sort could be done. Dr. Watzin added that a launch vehicle for a next orbiter hasn’t been selected yet, so the amount of excess lift capability isn’t known yet. Last year, he found the CubeSats discussion to be a distraction for M2020 primary mission planning and directed that they be taken out of consideration at that time to focus on the primary mission. Once a launch vehicle is selected, the program can look at whether there is capacity left over for a rideshare. Dr. Luhmann commented that there had been a CubeSat demonstration scheduled to fly with InSight, and she asked if those demonstration projects were going to remain with InSight or could be considered for other flight opportunities. Dr. Green replied that those two CubeSats are intimately connected with InSight, as they are intended to provide detailed information on where InSight is at every point in entry, descent, and landing. So they will definitely be flying with it, under its new launch

schedule.

Dr. Neal asked if there was any thought about sending a second bare-bones communications satellite to ride with the next science and communications orbiter, since the next orbiter would be replacing both Odyssey and MRO. Dr. Watzin said that NASA engineers have certainly proposed that option from an engineering feasibility perspective, but currently the program is budget-constrained, and the program has to work within those constraints to move forward. There are some great engineering solutions that look feasible, he added, but without the budget to support them, MEP is compelled to stay with a more pragmatic solution. MEP will continue to look for opportunities such as TGO to boot-strap communications capability.

Dr. Horanyi asked for Dr. Watzin's "best guess" at when Mars samples might get returned to Earth. Dr. Watzin responded that he would consider the Mars Sample Return program a huge success if it could get samples back by the end of the 2020s. Dr. Pratt added that a big concern in the community is that samples will not be allowed out of secure storage (for scientific study) even if they make it back to Earth because the planetary protection issues have not been addressed in a way that would allow scientific study of the samples.

Ethics Training Session for PSS Members

During their working lunch, PSS members received their annual ethics training as Special Government Employees.

SMD Education CAN Selection

Ms. Kristen Erickson, Director of Science Engagement and Partnerships in SMD's Science Education office, returned to this meeting to provide follow-up information on the Education CAN, which she had briefed to the PSS at the October 2015 meeting. This presentation focused more on the process of the Education CAN, rather than details of who was selected and for what objectives, which she briefed in October. She noted that two of the awardees had been out in Indonesia covering the total solar eclipse on March 8 as part of the NASA Eclipse Education Program. Later in the briefing, she added that three of the awardees are targeted to providing education activities for the August 21, 2017, solar eclipse, for which the total-eclipse path traverses the United States.

After reviewing the organizational structure and staffing of the Office of Science Engagement and Partnerships, Ms. Erickson provided an overview of what has come to be called the "Collective" of the 27 Education CAN awardees under the SMD Science Education Program. In addition to awardees with expertise in one or more of the four science areas represented in SMD (planetary science, astrophysics, Earth science, and heliophysics), some awardees provide targeted dissemination mechanisms to particular audiences of interest, such as youth groups, libraries, planetariums, and underserved regions such as the upper Northwest. The Collective is structured to move toward the overarching outcome of having subject matter experts in NASA content more efficiently and effectively present in the learning environment for learners of all ages. The program period of 10 years is divided into a 5-year base period and a 5-year option period. An incremental approach is being taken to bring the Collective along; it starts with a needs assessment to determine evaluation criteria and metrics against which awardees'

performance will be measured.

A kickoff meeting that included all 27 awardees was held on January 19-21, 2016. Representatives from NASA Office of Education programs were invited to present, so awardees would know about activities that NASA is already undertaking. Each awardee also had time to brief the Collective, and the final day was used to develop and announce statements of cross-collaboration among the awardees. A total of 122 such statements resulted. Since the January kickoff meeting, the Collective has held weekly teleconferences to discuss logistics and how to get activities organized. Starting in March, the collective will hold 2-hour virtual sessions (teleconferences possibly with Webex video) monthly. The Collective also has a shared workspace at smdepo.org.

Each awardee will have internal evaluators who are independent of the awardee's effort but from within the Collective. There will also be an external evaluator assessing the Collective as a whole. The NASA Office of Education has been tasked to select the external evaluator through a Blanket Purchase Agreement. If an external evaluator is not in place by this summer, the program will rely on the NRC's Board of Science Education to do an external evaluations of the program's process and metrics. The Collective will have an annual review that all awardees will attend, with the first review scheduled for November 2016. This review will establish a program baseline and set the stage for calendar year 2017 activities.

Among the opportunities being pursued by the Collective are introducing SMD content and experts into areas and venues not previously involved in SMD science education activities, improved coordination across SMD science education, reduction in fragmentation and duplication of efforts, increased support of targeted audiences based on the needs assessments, and improvements in science literacy. With respect to the last of these areas, one of the Collective's awardees is Dr. John Miller, who for 30 years has led the National Science Foundation (NSF) team that prepares the biennial reports on science literacy indicators. He will be fielding a general survey on science literacy twice each year, with the results feeding back into the program to help improve the Collective's activities going forward.

Among risks and areas of concern, Ms. Erickson noted that the science education environment is currently particularly dynamic because of the changing requirements, objectives, and metrics coming from the Every Student Succeeds Act, which replaces the No Child Left Behind Act. The new legislation transfers oversight of Federal educational funding to the states. It is not yet known how each state is going to handle standards and educational grant awards. Another risk area is the budget uncertainty for continued funding of the Collective awardees. The FY 2016 Budget Appropriation for the program is \$37 million, compared with the FY 2016 President's Budget Request of just \$20 million. The FY 2017 President's Budget Request is for \$25 million. Ms. Erickson said that budget decision makers are looking for the program's metrics and some initial results before deciding to increase support further. A third area of concern is to fill the two major gaps identified in last summer's peer review of the program: one in formal education and the second in underserved areas.

As measures of achievement, the program has adopted progress by 2020 toward the goals set by the Committee on STEM Education (CoSTEM) of the National Science and Technology Council, statistical improvement in applicable science and engineering indicators and in scientific literacy

surveys by 2020, and budget support that reflects progress toward the program's desired outcome.

Ms. Erickson discussed how the SMD Science Education office supports the NASA Office of Education with both subject matter experts (SMEs) and planetary science content and how the past role of education and public outreach (EPO) professionals has evolved into the new role of [educational institution] relationship managers. She also summarized the education and outreach areas handled directly by the NASA Office of Education and how the offices at the two levels work synergistically.

Ms. Erickson next discussed the importance of NASA science education activities reaching what have been underserved population segments, not only for science education generally but also for sustaining and diversifying the NASA scientist development pipeline. She began by illustrating the changing demographics of the public school student population, with non-white students now in the majority. Among recent education-focused opportunities, she highlighted the NSF solicitation for NSF INCLUDES [Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science] and the NASA Office of Education Announcement for High Impact/Broad Implementation STEM Education Partnerships.

As her final topic, Ms. Erickson presented NSF science literacy indicators to highlight the lack of understanding in the general public of what scientists do and what the scientific process is. For example, in 2012 only about a third of the population had a basic understanding of scientific inquiry, and that proportion has not changed much over the 30 years that George Miller has been assessing science literacy for NSF. She sees improving science literacy as foundational work for the SMD Science Education office.

Questions and Discussion

Dr. Luhmann noted that a concern expressed at the October 2015 PSS meeting was the loss of subject matter expertise among the science discipline representatives working in the field. Ms. Erickson described a number of "strategic and tactical" actions that have been taken to provide resources to SMEs who lost the ability to charge time spent in science education and outreach. Science education forum funding has been extended throughout this year (although most funding ends in April), and she has asked the forum leads to ensure that their participants are aware of the Collective and its purpose, who the PIs are, and to provide feedback to the SMD Science Education office through the keep-in-touch tools on the smdepo.org website. Her office has also been working with SMEs who proposed to the Education CAN but were not selected. In addition, PSD has offered funding for up to 1 FTE for SMEs from approved extended PSD missions to interact with the Collective awardees. Other SMD divisions are beginning to agree to similar support on a mission-by-mission basis. Her office also has an AO team that is examining all PSD AOs to consider adding similar language [for funding SMEs to interact with Collective awardees]. Work is also in progress on a SME reach-back capability that would use Google Maps to connect SMEs with local educational needs. SMEs will be able to register through established programs such as Solar System Ambassadors or Night Sky Network. At NASA headquarters, a new writer has been hired to work on the people part of the Stories of Science program, using the solarsystem.nasa.gov website to showcase planetary science SMEs. Ms. Erickson sees some engineering education technology tools, such as those in Dr. Ariel Anbar's laboratory, being used to allow subject matter expertise to be communicated interactively with students and classrooms.

In response to a question from Dr. Luhmann, Ms. Erickson displayed a graphic showing the geographic distribution of both PIs and co-investigators for the Collective awardees. She also gave updated statistics on which of the 27 awardees included at least some content in each of the four science discipline areas: 17 awardee projects include planetary science content, 15 include heliophysics content, 16 include Earth science content, and 15 include astrophysics content. The selection rate was 37%, of which more than half (56%) were proposals from legacy institutions. Dr. Erickson also noted several awardees who have the flexibility and subject matter expertise to engage public interest in opportunities such as space-oriented movies such as *The Martian*. The smdepo.org site includes a calendar of upcoming EPO activities tied to special events such as the Juno's orbital insertion at Jupiter on July 4, which provides Collective awardees with a look-ahead at upcoming events of interest to their audiences.

Dr. Green asked if there are plans to provide coverage by the Collective in states that do not have an awardee, and Ms. Erickson described some of the actions aimed at expanding coverage to all interested states. A "reach map," which is being prepared, will show the extent of each awardee's geographical reach. She added that ensuring coverage for underserved areas is still a work in progress. Dr. House and Ms. Erickson described the work by Collective awardees and the avenues available to provide opportunities for undergraduates to participate in balloon-based observations during the 2017 solar eclipse.

In response to a question from Dr. Neal on details of the metrics for evaluating awardees' success, Ms. Erickson said that each awardee identified success metrics for that awardee's projects in the proposal, and they are required to perform in accordance with their cooperative agreement. For the Collective as a whole, a checklist of top-level indicators of success has been assembled. The indicators measure progress, performance, output, and outcomes. There will also be survey data to document results for STEM education of providing NASA SMEs, content, and authentic experiences for learners of all ages. Another program success metric is to show an increase in scientific literacy as measured by George Miller's NSF survey items. There are also metrics to evaluate the success of the objective of leveraging science education through partnerships. Ms. Erickson also described aspects of the Collective's projects that promote involvement in citizen science, including one awardee with a focus on ensuring scientific rigor in citizen science activities.

NExSS

Dr. Mary Voytek, SMD Senior Scientist for Astrobiology, updated the PSS on the Nexus for Exoplanet System Science (NExSS) research coordination network, which is a cross-division initiative. To understand exoplanets, particularly as potential habitable and inhabited worlds outside the Sun system, the initiative is taking a system science approach, as exoplanet research cuts across the science disciplines represented in the four SMD divisions. The concept was to leverage existing programs in SMD to advance the field of exoplanet research, specifically research in comparative planetology, biosignature and habitat detection, and planet characterization. Selections would be made from these already existing programs, and a mechanism would be established by which researchers in the programs could interact by bringing in a larger exoplanet community and thereby break down the barriers between divisions, disciplines, and stove-piped research activities.

The mechanism is a research coordination network, which Dr. Voytek defined as “a virtual structure to support groups of investigators to communicate and coordinate their research, training, and educational activities across disciplinary, organizational, divisional, and geographic boundaries.” She presented a list from the NSF website of what prior research coordination networks have accomplished, particularly activities that are not typically funded under a traditional research grant. For NExSS, she showed the research calls in each division that were selected as relevant to exoplanet system science.

Since NExSS involves no extra funding for specific research, Dr. Green and Dr. Voytek came up with six measures of success for the initiative: (1) Investigators carry out and propose interdisciplinary research through new collaborations that cross disciplinary boundaries. (2) NExSS produces different ways of using existing assets such as space telescopes. (3) NExSS spawns ideas for new and exciting missions. (4) NExSS identifies new targeted technologies that are needed for exoplanet system science but are not yet reported elsewhere. (5) NExSS influences the Decadal Surveys for both planetary science and astrophysics in terms of defining new areas of research in both disciplinary areas. (The Astrophysics Division (APD) was the first division approached; since then the Heliophysics Division has formally joined, and individual Earth Science Division scientists are participating.) (6) NExSS enhances international engagement.

A kickoff workshop for the network was held on April 20, 2015. A steering committee of PIs from the selected programs has been meeting monthly for the past year in a webinar/telecon format, with the first 6 months focused on presenting the science being done in each program, so that PIs from different divisions would learn what others were doing. After that, a series of activities were aimed at establishing areas of mutual interest, such as a white paper on “Laboratory Work for Understanding Exoplanet Atmospheres,” initially led by J. Fortney, an APD grantee, with contributions currently from 30 other authors, only half of whom were among the original NExSS members. A number are international collaborators. The aim of the paper was to identify laboratory work that was needed in order to understand exoplanet atmospheres. A draft of the white paper has been released for community comment, and the astrophysics participants view it as relevant to their next ROSES call, which will highlight the timeliness of laboratory astrophysics research in support of the James Webb Space Telescope (JWST).

NExSS has held one workshop (“Upstairs Downstairs: Consequences of Internal Planet Evolution for the Habitability and Detectability of Life on Extrasolar Planets,” February 17-19, Tempe, AZ) and has two others planned: a biosignatures workshop in July 2016 and an exoplanetary space weather, climate, and habitability workshop planned for Fall 2015. Dr. Ariel Anbar, who was one of the organizers of the first workshop, said that the goal was to bridge between the astronomical community, which is interested in biosignatures but doesn’t look very deeply into the planetary context that produces them, and the Earth science community, especially the solid Earth science community, which thinks a lot about how planetary context could affect surface conditions but has not thought much about exoplanets. One result will be a white paper identifying research directions. Another result is potential interest at NSF in cofunding other NExSS workshops.

In addition to the monthly webinars and PI telecons held since June 2015, NExSS hosts a website for open discussions and is developing a newsletter. The team members number around 80, and the total list including informal participants is a few hundred. Dr. Voytek listed additional workshop ideas that have been suggested and several of the cross-team, cross-discipline

collaborations occurring among NExSS members. NExSS is also providing material for a blog by Marc Kaufman called “Many Worlds.” A face-to-face meeting of the NExSS PIs is planned for May 2016 at NASA Headquarters and will include an exoplanet talk show produced for NASA TV. Another mark of success is that the Habitable Worlds program element in ROSES, which previously was just a PSD element, was listed in the 2016 call under Section E.4, which is the cross-disciplinary section.

During discussion, Dr. Voytek, Dr. Green, Dr. Luhmann, and other PSS members discussed a number of areas in which work done in PSD could be relevant to NExSS issues that would involve the astrophysics and heliophysics communities. The potential for involving NSF in NExSS was also discussed.

PDCO Update

Dr. Kelly Fast, followed by Mr. Rob Landis, provided an update on the PDCO, filling in for Mr. Lindley Johnson, the PDCO Program Executive and the Planetary Defense Officer. The office was established in January 2016 to coordinate planetary defense related activities across NASA and to coordinate both U.S. interagency and international efforts and projects that address and plan response to the asteroid impact hazard. The PDCO mission statement is to “lead national and international efforts to:

- Detect any potential for significant impact of planet Earth by natural objects
- Appraise the range of potential effects by any possible impact
- Develop strategies to mitigate impact effects on human welfare.”

The PDCO is organizationally within PSD and includes the NEO Observation Program, for which Dr. Fast is now the Program Manager. Other elements are the Interagency and Emergency Response Program and the Mitigation Research Program. The mission of the NEO Observations Program is detection and tracking of natural objects—asteroids and comets—that approach with 28 million miles of Earth’s orbit. It is also the U.S. component of the International Asteroid Warning Network (IAWN) and has provided 98% of new NEO detections since 1998. The original commitment by NASA in May 1998 to find at least 90% of 1 km and larger NEOs was reached by the end of 2010. The NASA Authorization Act of 2005 increased the scope of the program’s objectives and also made NEO detection, tracking, and research one of seven explicitly stated purposes of NASA. Under the 2005 Authorization Act, the size for NEOs to be detected was decreased to “equal to or greater than 140 m in diameter,” and the goal for the program was changed to achieving 90% completion of a NEO catalogue for this new size specification within 15 years (by 2020).

At the end of December 2015, 13,514 near Earth asteroids (NEAs) had been discovered, plus 105 comets. Of these NEAs, 1,649 come within 5 million miles of Earth orbit, 879 are 1 km or larger in diameter, and 153 of 1-km or larger NEAs come within 5 million miles of Earth orbit. Dr. Fast showed the statistically predicted population of NEAs by size and compared it with the number found for diameters from 10 m to 25 km. As the size decreases, the number in the predicted population at that size increases exponentially. Dr. Fast then showed a chart overlaying likely magnitude of effects from a collision as a function of NEA diameter. She also showed estimates of the number of detections still needed to meet the goal of 90% identification of NEAs that

are 140 m and larger in diameter.

In response to a question on whether the NEA population evolves in time, Dr. Green and Dr. Mainzer described processes such as interactions with Jupiter's gravitational field and inter-asteroid collisions that will change the population over time, although the time scale over which the population evolves is difficult to quantify. Dr. Mainzer explained that the 140 m or larger size for detection was selected by the NEO SDT in its August 22, 2003, report as the balance point between the risk of impact from smaller asteroids and the risk from interplanetary comets. Dr. Fast added that the NEO SDT has been reconvened and is re-examining its assessments based on all the current data on size distribution of detected NEAs.

Of the predicted population of 25,500 NEAs with diameters of 140 m or larger, those 1 km or larger that have been found represent just 4%. Those in the 0.3-1 km range that have been found represent another 13%, and the predicted number in that range not yet found is estimated to be 16% of the total. The identified NEAs in the range from 140 to 300 m represent another 7% of the total, but that leaves 60% of the 25,500 NEAs that have not been found yet and are in the range from 140 to 300 m in diameter. In other words, an estimated 76% (60% plus 16%) of the NEAs of diameter 140 m or larger have not yet been detected.

Next, Dr. Fast described the ground-based and satellite-based assets used in NASA's NEO Search Program. The two centers involved in cataloguing NEAs and determining their orbits are the Minor Planet Center of the Smithsonian Astrophysical Observatory and the Center for NEO Studies at Jet Propulsion Laboratory (JPL). Another graph showed how survey telescope assets have contributed to NEA discoveries over time, depending on their capabilities and the size of remaining undetected NEAs. As more capable telescopes have been added, the discoveries have included more NEOs smaller than 140 m. For example, in 2015 1,560 NEOs were discovered but only 526 were 140 m or larger.

Mr. Landis described NASA's NEO Observation Survey and Alert Process, including the PDCO Rapid Notification Process to be used in the event that a potential impact risk or a close flyby is identified. (A close flyby is predicted passage inside geosynchronous Earth orbit.) The Minor Planet Center does an initial orbit determination after a new NEO is detected, then the Center for NEO Studies calculates a precision orbit and makes follow-up observations using the NEO Survey assets. The process for Potential Impact Notification is being worked out through exercises with the Federal Emergency Management Agency (FEMA). For either a probability of potential impact greater than 1% or a close flyby, notification of potential impact goes through PDCO to the SMD Associate Administrator, then to the NASA Administrator, who informs the Executive Office of the President (EOP) and OSTP. When EOP acknowledges notification, the NASA Office of International and Interagency Relations disseminates notification to Federal agencies. If impact is predicted within U.S. territory, FEMA notifies Federal, state, and local emergency response organizations. If impact is predicted to be outside the United States, the Department of State notifies the affected nation(s). Mr. Landis noted that the speed of execution of notifications in this chain is directly proportional to the time remaining to impact.

Mr. Landis then described the object characterization process that aims to determine rotation, shape, precise orbit, size, and mass of an object with a 1% or greater probability of potential impact or a close flyby. He then described the NEO characterization assets and how they would

be used, including the Goldstone and Arecibo radar telescopes, the NASA Infrared Telescope Facility, and the Spitzer Infrared Space Telescope. Recent NEO discoveries that flew by in cis-lunar space were the October 31, 2015, “Great Pumpkin” flyby of a dead comet with a diameter of 600 m and the February 3, 2016, flyby at half-lunar distance of NEA 2016 CG18, which was 4-9 m in diameter.

Mr. Landis described the PDCO role in the Asteroid Redirect Mission (ARM) as identifying and characterizing potential targets for the mission, and he gave details on four NEAs that are being studied as potential candidates for the mission. ARM includes a “planetary defense” demonstration in which the spacecraft will orbit the asteroid for several months with the objective of shifting its orbit slightly.

PDCO is funding a group at NASA Ames Research Center for the Asteroid Threat Assessment Project (ATAP). They will study the composition of several potentially hazardous NEAs to model what would happen as the NEA enters Earth’s atmosphere and impacts the surface. The project deliverables are impact risk assessment tools including mitigation decision tools and a near real-time bolide reporting system.

PDCO has also participated in two impact emergency response exercises with FEMA. The impact scenario for the first exercise was 3-4 weeks advance notice of potential impact, with a point of impact off the East Coast, near Maryland. In that exercise, the participants found that nothing could be done except to evacuate and “take the hit.” The second exercise involved an impact near Houston, Texas, with 7 years to prepare. For that exercise, which was run as a “paper simulation” exercise, a mitigation mission was launched but was only partially successful. A 40-60 m object was still going to make impact, and evacuation was again the last-resort response. A third exercise is planned for Fall 2016, with the point of impact being near Pasadena, CA. Dr. Green commented on aspects of implementing an emergency response for these types of events that FEMA has learned by participating in the exercises.

With respect to international collaboration on NEO threat response, Mr. Landis described the role of the IAWN, which would determine impact time, location, and intensity, and the Space Missions Planning Advisory Group (SMPAG), which would provide potential deflection mission planning. The delegates to SMPAG represent the space-faring nations that might contribute to a deflection mission, and ESA is the current chair. IAWN is a much less formal organization that includes observatories of several nations, analysts, and modelers, as well as NASA. These bodies would inform the United Nations Office of Outer Space Affairs and the Committee on Peaceful Uses of Outer Space in the event of a credible impact threat. In 2015, there were about 20.6 million observations from 39 countries reported through IAWN. In his final slide, Mr. Landis outlined the mission concept for the Asteroid Impact & Deflection Assessment (AIDA), which would be a joint NASA and ESA mission to demonstrate asteroid impact hazard mitigation using a kinetic impact spacecraft to deflect an asteroid. AIDA would send two spacecraft to intercept the binary NEA Didymos in October 2022. The ESA component, the Asteroid Impact Monitor (AIM), would be a spacecraft to rendezvous with and orbit Didymos to monitor the effect of the kinetic impactor test by the NASA component, the Double Asteroid Redirection Test (DART), on the smaller member of the binary asteroid.

Questions and Discussion

In response to a question from Dr. Luhmann about preparing for the sociological aspects of an asteroid impact disaster, Mr. Landis described work the NEO Observation Program has been doing related to communications and preparing for population response to an impact notification.

Dr. McCoy asked if NASA or anyone else is studying how the United States would actually respond to a potential impact warning of perhaps a decade, given the history of the U.S. policy and decision-making response to warnings of global climate change. Dr. Green, Mr. Landis, and Dr. McCoy discussed the role of international coordination bodies in contrast to the national decision-makers who would or would not take action. Dr. Green said he did not know of any investments in that area but agreed that research on the issue will be needed. The NSF research area of hazard communication was mentioned as an alternative to NASA funding such work.

Dr. Chabot reported that the small bodies community is enthusiastic about the PDCO being established finally, after a number of top-level recommendations for it. Given the size of the problem and the current small staff of the PDCO, she asked how PSD sees the scale of PDCO staffing and activities in a year or longer. Dr. Green responded that PSD has been methodically working in this area and has gotten congressional direction. The effort began about 10 years ago with a \$4 million investment and has grown now to \$50 million a year, during a time when the overall NASA budget was declining sharply. The head of OSTP has notified Congress of NASA's approach and its work with other agencies on notification and response planning. As more NEOs are found, they will have to be catalogued and tracked; the problem is going to grow, not go away. Hopefully, the process has been started well enough in advance of the situation where a really big NEO is on an impact trajectory. But he does not see the current staffing level in PDCO doubling in the next year. The international activities, particularly the AIDA concept with ESA, are very important steps. This is not in the current Planetary Decadal Survey, but he anticipates it being a topic for the next Decadal Survey.

Dr. Fast and others discussed the role of the NEO SDT, which has been reformed and will report to PSD in Fall 2016. There was also discussion of whether and how the operational response to a predicted impact event might eventually move to another directorate within NASA or to another government entity outside NASA, with planetary science remaining in a knowledge-gap-filling and advisory role. The participants discussed the interplay of policy and operational decision-making with resolution of NEO orbital uncertainty and drew analogies between NEO planetary defense and space weather (with the operational transition of DISCOVER to NOAA), as well as the development of meteorological satellites. Another topic of discussion was the progress toward international cooperation and participation in both NEO discovery and impact mitigation response.

Discussion

The PSS used this session to discuss potential topics for findings, including the proposed Ocean Worlds mission them in NF 4, the restructured R&A program, the Europa lander mission, planetary protection in relation to MEP and Mars Sample Return, and responses to formal establishment of PDCO and the planetary defense mission.

In response to a question, Dr. New reminded the members that, under FACA, findings and recommendations of the subcommittee have to be formulated and decided upon in public session.

NAC Planetary Science Subcommittee Meeting, March 9-10, 2016

The preliminary discussion of topics and wording for findings ended at 5:12 p.m., and the meeting was adjourned for the day.

March 10, 2016

Agenda Updates and Announcements

Dr. Luhmann opened the session. Dr. Green acknowledged retiring PSS member Dr. House.

Analysis Groups Quick Update, Q&A, and Discussions

Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM)

Dr. McSween, CAPTEM chair, briefed the PSS via teleconference and Webex. The next CAPTEM meeting is March 19, and Dr. McSween discussed the topics on the agenda for that meeting. One of the topics is scientific data management standards for the curated-sample analysis community, a topic that Dr. McSween sees fitting in well with the new PSD requirement for DMPs in R&A proposals.

As two recent science highlights” from the CAPTEM community, Dr. McSween spoke about a recent publication on formation of the chondrules in chondritic meteorites as a result of impact jetting and another publication on the incorporation of primordial water into the most ancient rocks in terrestrial planets.

Current issues of concern for CAPTEM include delays in Discovery and New Frontiers AOs because some of these opportunities could involve sample return, continued funding pressures on extraterrestrial materials research, and interest in the NRC review of the R&A program. CAPTEM also wishes to contribute to the white paper being formulated by the AGs on the importance of having Participating Scientists involved with NASA missions.

Dr. McSween brought up concerns expressed by members of CAPTEM that the PSD Facilities RFI indicated a change in approach for funding instrument development in individual laboratories. This led to discussion among PSD staff and PSS members about the funding streams for acquiring new instruments, revisiting the previous day’s discussions about community concerns related to the Facilities RFI, and issues related to difficulties in funding expert technical support staff in planetary science laboratories. On the technical support problem, there was discussion of drafting a white paper to help NASA understand the problem and/or a PSS finding. Past efforts by CAPTEM to deal with issues related to declines in funding for planetary materials R&A were brought up by PSS members, and PSD staff responded with suggestions on additional information that would be helpful to address the problems raised. Other PSS members noted that the funding issues for laboratories, instrument development, technical support staff, etc., apply across the science disciplines (beyond just the CAPTEM community), and the need for and content of a crosscutting white paper, perhaps by a subgroup of the PSS, was debated. Whether the AGs together adequately represent all the planetary science communities and whether they would, in concert, have sufficient status compared with a PSS subcommittee (for example) were issues raised in the context of how best to proceed with formulating community concerns and potential solutions on the laboratory support issues. Communication and representation venues

for communities (such as astrobiology) that are not closely aligned with any one AG were discussed.

Outer Planets Analysis Group (OPAG)

Dr. McEwen, OPAG chair, briefed the PSS on the OPAG charter and both recent and upcoming meetings. He detailed the major objectives set for the next full OPAG meeting is on August 11-12 in Flagstaff, AZ. The challenge for the OPAG community, Dr. McEwen said, is a “decade of darkness” between the recent/current outer planet missions (e.g., Cassini and Juno) that are now at their target bodies now and the time when the next generation of outer planet missions arrives at their targets. The OPAG has compiled a set of recommendations on how to minimize the impact of this decade of darkness on the science community.

Dr. McEwen presented an OPAG finding in support of an Ocean Worlds program and noted that a strategic planning group has been formed to develop an Ocean Worlds scientific roadmap. The group is drawn broadly from the outer solar system community, including OPAG and SBAG, and will develop goals and strategies. Two other OPAG findings expressed appreciation of R&A increases in the FY 2016 budget, and OPAG concerns about data reception outages by the Deep Space Network (DSN).⁷

Dr. Green responded that the DSN outages are a hot topic inside NASA, but there is no decision yet on what to do about it. He and Dr. McEwen discussed the history of DSN being placed under the Human Exploration and Operations Mission Directorate (HEOMD) and subsequent network sustainment issues. Dr. Chabot suggested that the DSN would be a good topic for another PSS meeting, so all of the subcommittee could get educated on DSN issues. A PSS finding on DSN issues was discussed.

In another finding, OPAG noted that it favors a multiple flyby Europa mission with the earliest possible arrival date at Jupiter because that arrival will end the community’s “decade of darkness.” The OPAG has concerns about co-manifesting a lander on the same SLS because that could delay arrival. Dr. Green responded with comments on studies in progress for Europa mission options and the statutory language directing that the mission include both a multiple flyby and a lander. The going-forward plan for the mission is still a work in progress. He also discussed the rationale for and role of a SDT to define what the lander objectives should be. Dr. McEwen, Dr. Luhmann, and other members discussed a potential PSS finding on the Europa lander concept and the role for a SDT focused on the lander part of the Europa mission.

The OPAG finding on radioisotope power systems (RPS) expressed concern about the end-of-life power profile for the newer enhanced Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs), as end-of-life power can be an issue for Outer Planets exploration. Dr. Green agreed that this is an issue for missions using RPS and it is being investigated; he suggested that a briefing be planned for the next PSS meeting.

The OPAG finding on the legacy of Cassini voiced the community’s concern that funding for the

⁷Full text of the OPAG findings from the February 2016 meeting are available at <http://www.lpi.usra.edu/opag/meetings/feb2016/Findings.pdf>.

Cassini Data Analysis Program (CDAP) might be inadequate because the wealth of data from the latter part of Cassini will take time to analyze effectively. The finding encouraged extension of the CDAP and monitoring of the selection program.

Other OPAG findings expressed pleasure with progress on the Ice Giant mission study for the next Planetary Decadal Survey, supported inclusion of an Ocean Worlds mission theme in New Frontiers and urged release of the NF 5 AO before 2023, supported a five-mission-per-decade cadence for Discovery and the inclusion of RPS as government-furnished equipment (GFE) for Discovery proposals, encouraged broader use of Participating Scientist programs and mission support for early-career scientists, recommended facilitation of cooperative activities with foreign-led missions whenever appropriate, encouraged continued development of CubeSats and small instruments for planetary exploration, encouraged continued engagement of the planetary science community in development and operation of astrophysics assets that can be used to conduct remote sensing of bodies in the outer Solar System, and stated a preference for New Frontiers DAP proposals to be due after the second release of New Horizons data.

Dr. Luhmann asked whether planetary protection requirements would be addressed by the Ocean Worlds roadmap. This led to discussion of who in the scholarly community represents planetary protection and why and how to include planetary protection in early planning for planetary science missions. Dr. Voytek suggested that the strategic planning group include a member of the Planetary Protection Subcommittee (of the NAC Science Committee). Dr. Chabot thanked the strategic planning group for reaching out to other AGs to participate. Dr. McEwen presented a tentative schedule for the roadmap activity, with a final report planned for the end of calendar year 2016.

Venus Exploration Analysis Group (VEXAG)

Dr. Lori Glaze, VEXAG chair, briefed the PSS on recent VEXAG activities, starting with the 13th VEXAG meeting at the end of October 2015. Two new reports include one from the Venus Exploration Targets workshop, held in May 2014, and another from the workshop on Science Priorities for Laboratory Measurements and Instrument Definition, held in April 2015.

Venus science nuggets include the entry into Venus orbit in December of the Japanese Akatsuki orbiter mission and a joint U.S.-Russian SDT for the Venera-D concept. Dr. Glaze presented details on both of these activities. An interim report from the Venera-D SDT is expected this summer.

Of the findings from the 13th VEXAG meeting,⁸ the finding on timing of the NF 4 AO has been addressed by the New Frontiers community announcement on January 6, 2016. Another finding was that reassessment is needed of the Venus Climate Mission, identified in the Planetary Sciences Decadal Survey as a flagship priority, to provide an in-depth science study in time for the next Decadal Survey. Other VEXAG findings expressed support for international collaboration in Venus exploration missions, particularly for support of Participating Scientists on

⁸ The findings (or deliberations summary) from the 13th VEXAG are available at www.lpi.usra.edu/vexag/meetings/archive/vexag_13/deliberations.pdf.

foreign-led missions to keep the U.S. community involved.

Finally, Dr. Glaze reported on upcoming and planned VEXAG activities and other meetings relevant to the broader Venus exploration community.

Lunar Exploration Analysis Group (LEAG)

Dr. Neal, LEAG chair, reported on the most relevant findings from the October 20-22, 2015, LEAG meeting.⁹ With respect to lunar polar volatiles, the LEAG community supported the selection of CubeSat missions to begin providing the higher spatial resolution needed to identify locations of lunar polar volatiles to inform future rover missions. A broad understanding of the types and distribution of lunar polar volatiles will require synthesis of multiple data sets, including new observations, and achieving this synthesis should be considered in Senior Review decisions with regard to LRO mission extensions. The temporal data sets from LRO, Dr. Neal added, are providing important information on how the lunar polar volatiles migrate.

Two other LEAG findings supported the HEOMD Resource Prospector Mission, which has a nominal launch date in 2020, and encouraged PSD to evaluate how this mission could address Planetary Decadal Survey goals and to explore avenues for the lunar science community to participate in the mission. There was additional discussion among PSS members about fostering and funding cross-directorate collaborations, particularly where science investigations can complement the objectives of HEOMD missions, with LRO as an example of both the opportunities and the challenges.

Dr. Neal covered upcoming and planned lunar science and LEAG activities, including a second *New Views of the Moon* book that will have more chapters (more writing teams) and more international participation than the first one. He described several Special Action Team (SAT) activities in HEOMD in which LEAG members participated and a LEAG Technologies Roadmap activity that will address necessary capabilities for lunar science. The annual LEAG meeting is scheduled for November 1-3, 2016. Dr. Neal presented several “science nuggets” on recent lunar science findings, several of which relate to lunar polar volatiles.

Small Bodies Assessment Group (SBAG)

Dr. Chabot, SBAG chair, reported to the PSS on findings¹⁰ from the 14th SBAG meeting on January 27-29, 2016, and on upcoming and planned activities in the small bodies community.

Among the SBAG findings were enthusiastic support for formation of the PDCO; reiterated emphasis on maintaining the Planetary Decadal Survey’s recommended cadence for Discovery missions; support for release of NF 4 by January 2017, to maintain the Decadal Survey cadence of two missions per decade; preference for limiting the NF 4 candidate missions to those either specifically identified as priorities by the Decadal Survey process or through a similar

⁹ The full set of 2015 LEAG findings is available at www.hou.usra.edu/meetings/leag2015/Meeting-Findings.pdf.

¹⁰ The complete findings from the 14th SBAG meeting are available at www.lpi.usra.edu/sbag/meetings/jan2016/Findings.pdf.

community-wide process if re-evaluation is necessary between Planetary Decadal Surveys; encouragement to NASA to continue support of the Arecibo Observatory and to find a funding formula that provides for the stability and productivity of Arecibo as a critical national asset; strong support for continued operation of the Dawn spacecraft through a mission extension; a request to consider enhanced NEO survey capabilities as a NASA-wide initiative, in light of the statutory direction to find at least 90% of NEOs larger than 140 m by 2020; support for the plan for a competed opportunity this year for membership on the ARM Investigation Team and for continued engagement between the small bodies community and the ARM team on mission formulation; encouragement to PSD to explore means of increasing funding for the R&A program to improve the selection rate for highly rated proposals; encouragement for speedy establishment of DAP programs for the New Horizons and Rosetta missions; and encouragement for a midterm Decadal Survey assessment to address ways of maintaining a healthy scientific community capable of supporting NASA's needs.

Dr. Chabot expanded on the context for the Arecibo finding, which grew out of a detailed briefing on Arecibo to the SBAG at its last meeting. This led to extended discussion of the issues related to Arecibo as jointly funded by NSF and NASA but still being a NSF-owned facility. The PSS discussed formulation of a PSS finding on Arecibo.

With respect to the SBAG finding on Dawn mission extension, Dr. New said that PSD is looking into an out-of-cycle Senior Review to consider it. Dr. Chabot noted that the SBAG finding on the NEO survey was intended to support making the survey more of a NASA-wide funding priority, rather than being entirely funded from the PSD budget. Dr. Green explained that the statutory requirement was in an authorization bill but has not been supported in appropriations, so any additional NASA effort has to come from existing budgets.

Dr. Chabot explained the context for the finding on community involvement in the ARM mission, and her discussion about it with Dr. Green clarified that the small bodies community, although enthusiastic about participating in ARM, does not support having ARM funding draw from PSD funds needed to meet Planetary Decadal Survey objectives. In particular, this caveat applies to the HEOMD plans for an ARM Investigation Team that would include members from the small bodies science community.

Dr. Chabot also expanded on the context of the SBAG finding on increasing funding for the R&A program and the finding on New Horizons and Rosetta DAPs. This led to discussion with Dr. Green on how the community views DAPs versus R&A funding and whether addition of DAPs funded through mission lines would be viewed by the community as a way to help with R&A funding issues.

Dr. Chabot reported that the SBAG Goals document is now available on the SBAG website, with about 10 pages of supporting text for each of the three main goals. She listed the SBAG Steering Committee members and noted that Dr. Tim Swindle will become the SBAG chair in August 2016. Upcoming SBAG meetings are scheduled for the end of June and then in January 2017.

Mapping and Planetary Spatial Infrastructure Team (MAPSIT)

This was the first PSS meeting with representation from MAPSIT, which was formed recently

through an interagency agreement between NASA and the U.S. Geological Survey (USGS). Dr. Samuel Lawrence briefed the PSS on the role of lunar and planetary geographic information from photography and cartography in enabling both planetary science investigations and planetary missions. He explained the role that his community sees *for planetary spatial infrastructure* to support the needs of mission formulation and mission operations within the decision cycles of managers running those activities. He described the range of technical specialties and capabilities that constitute the MAPSIT community and reviewed recent MAPSIT activities and products from the MAPSIT community. To illustrate the kinds of large-scale data products the community produces, Dr. Lawrence showed portions of a mosaic map, based on data from the Mars Odyssey Thermal Emission Imaging System (THEMIS) instrument, which was produced to support Mars rover operational planning.

Dr. James Skinner described the roles, past support to NASA, and technical capabilities of the Planetary Geologic Mapping program at USGS, which he manages. He also discussed the program's role in educating the user communities on what goes into a geologic map and what it provides. He talked about the inventory management process to pare the inventory down to just the most useful products for future needs. He also explained the difference between the standardized geologic maps produced only by the USGS program and the "topical science" maps that often appear in the planetary research literature. The program now has a specification document that helps to control and inform the lengthy process required to produce a standardized geologic map. The varieties and scales of geologic maps are increasing; the High-Resolution Imaging Science Experiment (HiRISE) instrument on MRO, for example, is enabling maps to be made to support MEP and human exploration missions at the same scale that is used for high-resolution geologic maps on Earth.

The annual meeting of geologic mappers occurs in June each year, and attendance has been increasing. The participants now include people doing standardized geologic maps and those doing topical science maps. Dr. Skinner talked about mechanisms for bringing more personnel with the requisite mapping expertise into the planetary mapping field to meet user requirements.

In response to a question on how planetary geologic mapping requirements are working after the R&A restructuring, Dr. Skinner described challenges in knowing what work selected proposals would bring to his program, but he also said that the new specifications document is working well in fostering communication with the user community and helping his program to stay abreast of users' requirements.

In response to another comment, Dr. New explained that a map product as part of a research project could still be funded under a DAP and did not necessarily have to be proposed to Planetary, Data Archiving, Restoration and Tools (PDART). Dr. Green stressed that R&A investigators who have a question about how to propose for funding to support map products and any other kind of data-related tool should contact their R&A Program Officer.

Among 2016 MAPSIT activities, there will be a session on planetary spatial infrastructure at the LPSC and an informal MAPSIT forum at the June 2016 mappers meeting. MAPSIT is also aiming to produce a planetary geospatial strategic plan to inform decision-making, along the lines of other strategic planning and goals documents developed by the other AGs. The goal is to deliver the document to USGS and NASA by the end of calendar 2016. MAPSIT will also begin

planning for the 3rd Planetary Data Users Workshop, to be held in 2017. Strategic knowledge gaps are being reviewed for each planetary body to assess where the gaps related to mapping still remain. Missions like LRO and MRO have brought new challenges related to how to manage and use effectively the huge data sets being delivered. With respect to prioritizing the workload, Dr. Lawrence said that “force-multiplying software investments” are important but prioritizing those investments against currently needed data products will require a community conversation.

Mars Exploration Program Analysis Group (MEPAG)

Dr. Pratt, the past-chair of MEPAG, noted that the first science results from MAVEN have been published as a special issue of *Geophysical Research Letters*, containing about 50 articles. MEPAG has put out a call for new members of its Goals committee as a way to encourage younger researchers to join and participate. The growth in international missions to Mars and preparation for human exploration mean that goals for MEPAG are evolving quickly.

The last MEPAG meeting was March 2-3, 2016, in Silver Spring, MD, and had between 120 and 130 participants, plus a strong telecon/Internet presence. When the meeting is held in California, in-person attendance is typically 250-300. This meeting had several international presentations including a presentation by the International Mars Exploration Working Group (IMEWG) on getting Mars samples back to Earth and having a sample handling facility ready so they can be studied. There was a lot of interest in the increasing coordination between SMD and HEOMD. Two reports from MEPAG Science Analysis Groups (SAGs) were accepted, one on Science Objectives for Humans on Mars (on humans working with and directing rovers) and the other from the Next Orbiter Science Analysis Group (NEX-SAG).

MEPAG endorsed the NEX-SAG report, including the SAG’s conclusions on the value of SEP for science investigations, resource identification (for human exploration) and providing capability for returning a cache of Mars sample to Earth vicinity. The MEPAG community had been concerned that, without SEP propulsion, incorporating capability on the orbiter for sample return would preclude a suite of remote sensing instruments for scientific observations.

In other findings,¹¹ MEPAG was encouraged by inclusion of \$10 million in the FY 2017 President’s Budget Request for a study of the next Mars mission. While agreeing with the importance of replenishing relay and site certification infrastructure to support future missions, MEPAG recommended that NASA make every effort to enable new science from orbit in addition to providing sample capture and return capability. MEPAG also supported MEP efforts in cross-directorate (SMD and HEOMD) and international collaborations related to the next orbiter mission and commended a list of Mars exploration opportunities being considered by other space-faring nations. However, a point of concern was that instruments donated to U.S. missions by other nations could preclude competed instruments that would fulfill Decadal Survey exploration objectives. Another concern was providing opportunities for the U.S. science community to compete for and be involved in achieving the science and resource investigation objectives of the next orbiter mission. A third concern was having a path for U.S. investigators to

¹¹ The MEPAG briefing slides to PSS, including the MEPAG findings, are available at science.nasa.gov/media/medialibrary/2016/03/15/MEPAG_Report_to_PSS_03-2016.pptx.pdf.

compete for whatever funds are available to support U.S. participation on foreign instrument teams, whether for U.S. or foreign-led missions.

While MEPAG supported additional joint study where HEOMD and SMD agree that joint activity is productive, it also stressed that MEP must continue to plan and implement a “robotic” Mars exploration program. Dr. Pratt explained that the burden has been increasing on the Mars Program Office to schedule assets for in-depth studies of candidate human landing sites. Another finding called for continued examination of planetary protection policy with respect to humans on Mars and the need to explore at least some Mars special regions as science targets.

Dr. Neal commented that the MEPAG findings related to U.S. investigators having opportunity to compete for participation on foreign-led instrument teams and missions applied to other AGs as well. This point led to discussion of a potential PSS finding on commending collaborations but also ensuring that the U.S. community has participation opportunities.

Upcoming activities and events of importance to the MEPAG community include the TGO launch scheduled for March 14, the plans for the ORDT for the next Mars orbiter, a MEPAG virtual meeting to be held in Fall 2016, and the formulation of new MEPAG SAGs this fall.

Q&A Session with the Subcommittee

There were no questions to the PSS from visitors present at the meeting or those listening in via teleconference.

Findings and Recommendations Discussions

The PSS discussed findings on the following topics:

- The restructured R&A program
- An Ocean Worlds program and the proposed inclusion of an Ocean Worlds mission theme in the fourth New Frontiers AO.
- Europa Lander concept
- Planetary protection strategies for special regions on Mars and other bodies
- Support for U.S. investigator participation in foreign-led missions
- Mars sample return strategy (and sample return from other Solar System bodies)
- Establishment of the PDCO and PDCO mission areas
- Laboratory funding and sustaining expert technical support
- Deep Space Network
- Arecibo Observatory

The next meeting of the PSS is tentatively scheduled for June 7, 2016, but the date will be confirmed through an email poll of the members. Dr. Luhmann adjourned the meeting at 4:06 p.m.

PSS Findings from the March 9-10, 2016, Meeting at NASA HQ

Europa Mission

The PSS applauds the strong backing for a Europa mission and supports the goal to launch no later than 2022 to enable arrival of a spacecraft at Europa as early as 2025. We applaud the progress made with instrument selection, accommodation, and mission formulation for the multiple flyby mission. The PSS encourages the plan to carry the lander in a separate, independent spacecraft, which minimizes some of the risk of delaying arrival at Europa. The PSS looks forward to the Europa Lander Science Definition Team report including how the science goals outlined in the Decadal Survey will be met by the Europa lander, as directed by Congress.

Ocean Worlds

We applaud the public and legislative interest in ocean worlds that has been spurred by recent discoveries related to the possibility of extant life in the oceans of Europa, Enceladus, and Titan. The increased resources made available to PSD significantly enhance future efforts to explore these special, astrobiologically-relevant environments.

To maximize the scientific return of the Ocean Worlds initiative, we support NASA's continued engagement of the science community through roadmapping activities, including the Outer Planets Assessment Group's (OPAG) Roadmaps to Ocean Worlds (ROW). These community-based roadmapping activities optimize the balance of research objectives and scope for small, medium, and large missions. The OPAG ROW final report is expected by December 2016 and will provide input for the expected mid-term Decadal assessment.

PSS encourages PSD to put in place as soon as possible a process to integrate community input into the incorporation of Ocean Worlds into the New Frontiers program. The Planetary Decadal Survey has much content on how to respond to new discoveries but Ocean Worlds were not (at the time of writing the last Decadal Survey) fully vetted as a New Frontiers mission concept. A major part of that process is the establishment of the science objectives and subsequent confirmation that implementation concepts exist that can achieve those objectives within the New Frontiers cost cap.

The PSS encourages PSD to ask the Committee on Astrobiology and Planetary Science (CAPS) to consider whether inclusion of Ocean Worlds in NF-4 can be done via the processes and practices available to the agency and the community. CAPS should help to identify the path for taking advantage of similar exciting opportunities of this nature going forward.

Mars Sample Return

The path to returning samples from Mars to Earth begins in earnest with the launch of the Mars 2020 drilling caching rover. The international Mars community has prepared a study of crucial elements in sample return including design considerations for a clean-lab facility where the landed canister can be opened in order to interrogate the contents of the sample tubes and, ultimately, to open the sample tubes so scientific study of material from Mars can progress. These

design concepts may be relevant to the study of samples returned from other targets as well. In light of recommendations from the International Mars Architecture for the Return of Samples (iMARS) and International Mars Exploration Working Group (IMEWG), the PSS recommends a comprehensive and dedicated study of these design concepts in the context of both sample retrieval and a returned sample facility to handle and manage scientific study of samples.

Special Regions

Scientific interest has increased markedly in planning robotic missions that target Special Regions on Mars and ice-covered ocean worlds in the outer Solar System. Such regions are arguably the best choices for any meaningful search for extant extraterrestrial life, as well as for preparation for human exploration missions that contact planetary surfaces. Mission definition and engineering of spacecraft and instruments will require close coordination between the science community and the planetary protection offices at NASA and other space agencies. It is imperative for NASA and the National Academies to address how best to improve communication and to resolve conflicts related to robotic exploration of sites with seasonal or persistent liquid water. For planetary settings like Mars with discrete Special Regions rather than oceans, designation of particular areas of these regions for scientific study should be considered.

Assessment of Reorganized R&A

The PSS recognizes the amount of effort required to compile information on PSD program elements in the reorganized R&A program and appreciates the thorough summary presented at the meeting on funding level by planetary body based on key words. We especially applaud the development of key word analysis tools that will allow assessment and reporting of programmatic balance in future years. The PSS continues to request the release of data on selection rates by panel score for new core program elements (e.g., EW, HW, SSW) and encourages continuing public release on a yearly basis on selection statistics, selection rates by panel score for core program elements, funding level by planetary body based on key words, and statistics on the time required for determining selectable and selected proposals relative to proposal submission and review.

One concern noted by the PSS is that the selection rates described (average of ~21%) may mean that an investigator can receive scores of Very Good (4.0) or Very Good/Excellent (4.5) and still not be selected for funding by NASA. Because of the timing of the R&A reorganization and the impending termination of older funding programs (e.g., PG&G, Cosmochemistry, etc.) within the next year, it will be possible to have >30% of the R&A-funded community that routinely receives high proposal scores (4.0-4.5) not selected for funding. Nevertheless, the PSS applauds PSD for efforts to fund early career investigators and ensure the future of our community, even in a challenging funding environment. The PSS recognizes that one solution to this problem is more funding, and encourages NASA to continue to work to increase the level of funding for R&A programs in future years.

Planetary Laboratories, Facilities, and Technical Support

Laboratory instruments and facilities are critical for analyzing extraterrestrial materials, terrestrial materials that inform planetary exploration and data analysis, constraining the interpretations of planetary remote sensing data, and developing future flight instrumentation. The community perceives that a significant proportion of such laboratories to the point at which the science they support is put at risk.

PSD is concurrently assessing the need for facilities that can serve the broader community rather than individual PIs and research teams. Because instrument development is generally done in PI laboratories rather than in facility-level laboratories, both types should be included in PSD's research portfolio.

NASA has supported laboratories and major instrumentation for many years. It is becoming increasingly difficult to maintain technical staff support, placing stress on the community's research and training needs. The PSS will obtain community input, through the AGs and other avenues as appropriate (e.g., the NAI), about the number and type of PI laboratories that undertake research supporting PSD objectives, and their technical staff support models. This is to understand the planetary community's capabilities and challenges, and define the magnitude of the stress on research and training needs. The requested information will be used to inform discussions with NASA PSD about the challenge and help formulate potential solutions.

Deep Space Network (DSN)

The PSS is alarmed by reports of increasing data losses by active planetary missions (e.g. Cassini, with details provided by OPAG in their February 2016 finding on the DSN), especially following a 10% funding cut to the DSN at the end of 2015. The PSS supports aggressive efforts to address this issue and would like to hear updates as soon as possible. In particular, current NASA science missions using the DSN should be asked to inform NASA about recent DSN performance changes they have experienced.

Arecibo Observatory

Arecibo Observatory provides a unique capability for a range of cutting-edge science, including planetary science, as well as planetary defense and NASA's human and robotic exploration missions. However, there is concern about a potential NSF divestment in Arecibo facilities and maintenance. The PSS encourages NASA to continue its current support of Arecibo and urges NASA to continue discussions with NSF to preserve the nation's science and security interests and provide for the stability and productivity of this critical national asset.

Planetary Defense Coordination Office

The PSS welcomes the establishment of a Planetary Defense Coordination Office (PDCO) within the Planetary Science Division. We feel that this is an important step for NASA, as it responds to the need for detection of Near Earth Objects, and the necessary planning and coordination needed

to address planetary defense. Notably, the creation of the PDCO was a top recommendation by the 2010 NASA Advisory Council Planetary Defense Task Force.

US Participation in Foreign Planetary Science Missions

Other nations are continuing to develop planetary science exploration capabilities and plans, to which NASA can potentially contribute, toward achieving Decadal Survey science goals. PSS urges PSD to evaluate US opportunities to participate in and use data from foreign missions to planetary destinations throughout the Solar System, within the constraints of current State Department restrictions.

Appendix A
Attendees

Subcommittee Members

Janet Luhmann, **Chair, Planetary Science Subcommittee**

Ariel Anbar, Arizona State University

Nancy Chabot, Applied Physics Laboratory, The Johns Hopkins University

Nancy Chanover, New Mexico State University (*by telephone and Webex*)

Lisa Gaddis, Astrogeology Science Center, U.S. Geological Survey

Lori Glaze, NASA Goddard Space Flight Center

Mihaly Horanyi, University of Colorado

Christopher House, Pennsylvania State University

Samuel Lawrence, Arizona State University

Amada (Amy) Mainzer, Jet Propulsion Laboratory

Tim McCoy, Smithsonian Institution

Harry V. McSween, University of Tennessee (*by telephone and Webex*)

Clive R. Neal, University of Notre Dame

Larry Nittler, Carnegie Institution of Washington

Lisa M. Pratt, Indiana University

James Skinner, U.S. Geological Survey

Anne Verbiscer, University of Virginia

Jonathan Rall, Executive Secretary PSS, NASA HQ

NASA Attendees

Gabriel Adler, NASA HQ

Dwayne Brown, NASA HQ

Janice Buckner, NASA HQ

William Cook, NASA

Doris Daou, NASA/SSERVI

Kristin Erickson, NASA HQ

Kelly Fast, NASA HQ

James Green, PSD, NASA HQ

Jeff Grossman, NASA HQ

Jeff Johnson, APL

Rob Landis, NASA HQ

Tom Morgan, NASA KSFC

Michael New, NASA HQ

Curt Neibur, NASA HQ

Sarah Noble, NASA

Betsy Pugel, NASA HQ

Mitch Schulte, NASA HQ

David Schurr, NASA HQ

Mary Sladek, NASA HQ

Tom Statler, NASA HQ

Meagan Thompson, NASA HQ

NAC Planetary Science Subcommittee Meeting, March 9-10, 2016

Mary Voytek, NASA HQ
NASA Attendees, continued
James Watzin, NASA HQ
Curt Wiebun, NASA HQ

Other Attendees

Sara Barber, HSST
Linda Billings, NIH
Dwayne Day, ASEB, National Research Council
Jared Leisner, ASTS, Inc.
Steve Mackwell, USRA LPI
Alfred McEwen, University of Arizona
Amy Reis, Ingenicomm
Gregg Vane, NASA JPL
Ana Wilson, Ingenicomm
Robert Katt, Ingenicomm

Webex and/or Telephone Conference Attendees

Brent Archinal, USGS
Louis Barbier, NASA
Bar Bie, NASA
Dwayne Brown, NASA
Jonathan Chalton, Health Science Committee
Matthew Chojnacki, University of Arizona
Stephen Coark, Spaceflight Now
Barbara Cohen, NASA MSFC
Erin Dallas, NASA
Kelly Fast, NASA
Lori Feaga, Univ. of Maryland
Grace Hu, Office of Management and Budget
Gordon Johnston, NASA HQ
Dan Kane
Michael Kaplan
Jennifer Kearns, NASA HQ
Brook Lakew, NASA
Jared Leisner, NASA
James Lochner, Universities Space Research Association
Paul Mahaffy, NASA GSFC
Ralph McNutt, Applied Physics Laboratory, The Johns Hopkins University
Betsy Pugel, NASA HQ
Kurt Retherford, Southwest Research Institute
Christy Rivera, NASA HQ
Gilbert Rivera, NASA
John Rummel, Senti Institute, East Carolina University
Joan Salute, NASA
Erin Skalak, NASA

NAC Planetary Science Subcommittee Meeting, March 9-10, 2016

Sarah Stewart, Univ. of California, Davis

George Tahu, NASA

Tommy Thompson, JPL, NASA

Alexandra Witze, Nature Magazine

Alexandra Woodsey, Nature Magazine

Appendix B
Membership Roster
Planetary Science Subcommittee

Janet Luhmann, Chair
University of California, Berkeley

Ariel Anbar
Arizona State University

Nancy Chabot
The John Hopkins University
Applied Physics Laboratory

Nancy Chanover
New Mexico State University
Astronomy Department

Lisa Gaddis
U.S. Geological Survey
Astrogeology Science Center

Lori Glaze
NASA Goddard Space Flight Center

Candice Hansen-Koharccheck
Planetary Science Institute

Mihaly Horanyi
University of Colorado
Laboratory for Atmospheric and Space Physics and Dept. of Physics

Christopher House
Pennsylvania State University
Department of Geosciences

Samuel Lawrence
Arizona State University

Amanda Mainzer
Jet Propulsion Laboratory

Timothy J. McCoy
Smithsonian National Museum of Natural History

NAC Planetary Science Subcommittee Meeting, March 9-10, 2016

Harry McSween
University of Tennessee
Department of Earth and Planetary Sciences

Clive Neal
University of Notre Dame

Larry Nittler
Carnegie Institution of Washington

Lisa M. Pratt
Indiana University

James Skinner, Jr.
U.S. Geological Survey

Anne Verbiscer
University of Virginia

Jonathan Rall
Executive Secretary
NASA Headquarters
Science Mission Directorate: Planetary Science Division

Appendix C
List of Presentation Materials

1. Planetary Science Division Status report; *James Green*
2. Planetary Science R&A Program Update; *Michael New*
3. NASA Mars Exploration Program Update to the Planetary Science Subcommittee; James Watzin
4. SMD Science Education Status: Presentation to the Planetary Science Subcommittee; *Kristen Erickson*
5. NExSS: The Nexus for Exoplanet System Science; *Mary Voytek*
6. Planetary Defense Coordination Office Brief; *Lindley Johnson*
7. Community Comments: CAPTEM; *Harry McSween*
8. Community Comments: OPAG; *Alfred McEwen*
9. Community Comments: VEXAG; *Lori Glaze*
10. Community Comments: LEAG; *Clive Neal*
11. Community Comments: SBAG; *Nancy Chabot*
12. Community Comments: MAPSIT; *Samuel Lawrence*
13. Community Comments: MEPAG; *Lisa Pratt*

Appendix D
Agenda

Planetary Science Subcommittee Meeting

March 9 and 10, 2016
NASA Headquarters
Washington D.C.

Wednesday, March 9, 2016, 8:30 a.m. – 5:00 p.m. (5H41)

8:30	Welcome, Agenda, Announcements	(J. Luhman, J. Green, J. Rall)
8:40	PSD Status & Findings Update	(J. Green)
10:00	Break	
10:15	PSD R&A & Findings Update	(J. Rall)
11:15	Mars Exploration Program + Mars 2020 Update	
12:00	Lunch	
1:30	SMD Education CAN Selection	(K. Erickson)
2:30	NExSS	(M. Voytek)
3:00	Break	
3:15	PDCO Update	(L. Johnson)
4:00	Discussion	(All)
5:00	Adjourn	

Thursday, March 10, 2016, 8:30 a.m. - 5:00 p.m. (5H41)

8:30	Agenda Updates & Announcements	(J. Luhmann, J. Rall)
9:30	Analysis Groups Quick Update and Discussions	(10 mins each)
10:30	Break	
10:45	Analysis Groups Q&A and Discussions	(All)
12:00	Lunch	
1:30	Q&A Session with the Committee	(All)
2:30	Findings and Recommendations Discussions	(All)
5:00	Adjourn	

Teleconference Information:

Toll free conference call number: 1-888-603-9741, Pass code: 863162#

WebEx Link:

<https://nasa.webex.com/>

Meeting number for March 9: 998 136 809; **Password:** PSS@Mar9

NAC Planetary Science Subcommittee Meeting, March 9-10, 2016

Meeting number for March 10: 999 111 391; Password: PSS@Mar10