NASA ADVISORY COUNCIL

Planetary Sciences Subcommittee

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MEETING MINUTES

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Clive Neal, Acting Chair

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Jonathan Rall, Executive Secretary

Table of Contents

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Welcome, Agenda, Announcements

Dr. Jonathan Rall, Executive Secretary of the Planetary Sciences Subcommittee (PSS) of the NASA Advisory Committee (NAC), welcomed the meeting participants. After asking the PSS members to introduce themselves, Dr. Clive Neal, Acting Chair of PSS, reviewed the PSS terms of reference. He made the point that biological planetary protection is outside the scope of the PSS charge, instead falling to the Planetary Protection Subcommittee (PPS). However, there are overlapping issues, and the PPS Chair, along with NASA's Planetary Protection Officer, would make presentations at this meeting.

PSD & R&A Status and Findings Update

Dr. Rall presented the Planetary Science Division (PSD) update on behalf of the Division Director, Dr. James Green, who could not attend the meeting.

Mission Status and Science Highlights

Dr. Rall began by showing the PSD mission fleet. He noted that the European Space Agency's (ESA's) ExoMars 2016 mission was to arrive within a couple of weeks. A review of PSD accomplishments showed that since the last PSS meeting, the Juno mission had been inserted into Jupiter's orbit, and the Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) mission to the asteroid Bennu had launched. Another important development, though not related to the PSD missions, was the recent appointment of Dr. Thomas Zurbuchen as the Associate Administrator (AA) of NASA's Science Mission Directorate (SMD).

Dr. Rall next reviewed the status of the Discovery program, which has nine completed missions and four in development. From the 2014 call, there are five proposed missions in Step 1; PSD will down-select late in 2016. The New Frontiers program has three current missions: New Horizons, Juno, and OSIRIS-REx. Juno is now in orbit around Jupiter and will provide more precise data about Jupiter's origins, interior, atmosphere, and polar magnetosphere. Dr. Rall described the science orbits, which will begin soon. The orbits will lead to increasingly harsh radiation exposure, diminishing the instruments. Ultimately, in 2018, the orbiter will crash into the planet. All OSIRIS-REx instruments are fully operational. The mission will collect and return a sample, while also mapping the asteroid. Bennu has potential to become a hazardous object when it passes between Earth and the moon in 2135, with any actual hazard manifesting between 2175 and 2199.

New Frontiers Community Announcements were issued in January and April of 2016, with six investigation themes. Among these was "Ocean Worlds,")," addressing science objectives recommended in the last Decadal Survey (DS). A final Announcement of Opportunity (AO) will be issued by January of 2017, anticipating a Launch Readiness Date in 2024.

Small Innovative Missions for Planetary Exploration (SIMPLEx) selections included two full missions, the Lunar Polar Hydrogen Mapper and the CubeSat Particle Aggregation and Collision Experiment. PSD also chose three SIMPLEx cubesats for technology development studies. The National Academy of Sciences (NAS) released a report on NASA's use of cubesats for science, recommending that these satellites be used to address cost, risk, and flexibility issues, among others. PSD has responded by issuing a new Research and Analysis (R&A) element encompassing cubesats, and through the SIMPLEx program. The idea is to provide opportunities for cubesats on every planetary launch. The cubesats will be addressed in a separate AO. PSD is learning that cubesats are not as inexpensive as expected, so there will have to be standards in place, which will add to the costs.

Dr. Alfred McEwen said that a big advantage of using cubesats was supposed to be that they did not have to adhere to the usual standards. Dr. Rall explained that some of the primary missions are unwilling to add what they perceive as risk. Because there is intertwining of the cubesats and the main payload, there will have to be requirements. Dr. Neal observed that the cubesat program seems to be evolving from its initial intent of a "rideshare" to adherence to project guidelines. He asked if a trade study had been done to assess viability. Dr. Rall replied that a NASA launch will involve certain requirements. As for commercial enterprises, the insurers of those flights will have their own stances. SIMPLEx-1 will help bring forward the real costs. He did know that the original budget of $5.1 million was too low.

PSD has an active balloon research program. Dr. Rall noted the Gondola for High Altitude Planetary Science (GHAPS) device, which is a reusable balloon platform, is currently in development. Another mission concept is the Double Asteroid Redirection Test (DART), which will test asteroid impact mitigation with a kinetic impact technique demonstration. ESA is developing a related mission to the same asteroid system, the Asteroid Impact Mission (AIM). The combined effort is known as Asteroid Impact and Deflection Assessment (AIDA).

R&A Program Update
Dr. Rall next presented a timeline of PSD's Research Opportunities in Space and Earth Science (ROSES) 2016 deadlines. Concepts for Ocean Worlds Life Detection Tech (COLDTech) is a new R&A program. The Division is preparing another ROSES AO for February 2017. Dr. Neal asked about the Lunar Data Analysis (LDAP) exclusion of Apollo data. Dr. Sarah Noble of PSD explained that LDAP was created to direct attention to new data; investigators wishing to look at older data can go through the Solar Systems Workings (SSW) program. Dr. Rall added that PSD does not want to have a Data Analysis Program (DAP) specific to each mission. He presented the selection metrics by score, along with data on the time between decision and award.

The R&A program conducted a keyword analysis in three categories:

1. Type of task
2. Objects of study
3. Science discipline

The analysis included R&A awards, DAPs, participating scientists, and guest investigator programs, excluding support activities and facilities. Dr. Rall presented a breakout of the funding by keyword for each of the three categories. He noted that the R&A restructuring took place between 2014 and 2015. For each of the three categories, the amount of funding sent to areas without keywords has gone down over time, showing increased use of keywords.

Next, he discussed NAS studies for planetary science. The cubesat review was completed in 2016. The R&A restructuring review is ongoing, to be completed by the end of 2016. A report on large strategic science missions is due in August 2017, and the mid-term evaluation should be completed by the end of 2017. PSD was preparing to submit to NAS a request for a new study on the sample analysis future investment strategy. Finally, the next DS will be tasked to NAS before October 2019. Dr. Rall showed PSS the management request to NAS on a request for an ad hoc committee to assess Sample analyses capabilities. The statement of task has the committee assessing existing capabilities for analysis and curation of existing and future extraterrestrial samples, and requests recommendations for the future of this capability.

Among the findings from the PSS virtual meeting in June was one regarding communications about Mars sample return (MSR) and other developments. PSS stated that it was encouraged to hear positive updates about ongoing trade studies of Mars sample retrieval architectures. Industry participation will spur rapid development of these architectures. PSS encouraged PSD to provide frequent updates, opportunities for

dedicated science involvement, and more frequent communications about other developments. The PSD response was to state that the Division agreed. To that end, there were to be presentations at this meeting.

Another recommendation concerned a PSS study on labs led by Principal Investigators (PIs). The survey revealed concern about sustainability of labs doing critical work for the PSD missions. PSS therefore encouraged PSD to discuss the concerns and to create a committee to identify the specific lab capabilities that are critical to the Division. The PSD response was to charge NAS with this task.

PSS Structure
Ms. Elaine Denning, Executive Secretary of the NAC Science Committee, explained that each SMD science division has a subcommittee that reports to the Science Committee. NASA plans to revise the charters so that these subcommittees become full committees. In the current structure, the subcommittees, which are very productive, must take their findings and recommendations for NASA through the Science Committee, which in turn must go through the NAC. The change will send the tactical advice to the right level within NASA, formalize the advice and response functions, and promote efficiency.

PSS will become the Planetary Science Advisory Committee (PAC). The revised charter will be quite similar to the current terms of reference, while the membership balance plan will include areas of expertise. At the moment, the plan is with the General Services Administration (GSA) for review. The next steps will be publication in the Federal Register, then filing with the NASA Administrator and Congress. Subcommittee chairs will continue to serve on the Science Committee. The new committees will be able to bring in presenters from any area and set up task forces. The status of the Analysis Groups (AGs) is being worked through with GSA. Ms. Denning agreed that it would be difficult to require compliance with Federal Advisory Committee Act (FACA) regulations by the volunteers belonging to the AGs. She expected the change to take place within two months.

Discussion
In response to a question from Dr. Anne Verbiscer, Dr. Rall said that be believed the GHAPS funding came from Discovery futures, which was confirmed later in the day by Dr. John Rummel.

Next steps on the keyword analysis involve reducing the number of missing keywords. There is a substantial list of keywords, not all of which are used, so it would also be good to establish a basic set that makes sense. At present, the program officers enter the keywords, which can change with staffing shifts. He is considering asking the review panels to make recommendations to the program officers. A group will have better consistency. He had some concern about PIs designating keywords, as they are not always accurate and it is possible to game the system with keywords. Regardless, PSD needs a better way of handling this.

In response to a suggestion, Dr. Rall agreed that it would be possible to release the top-level funding number for each Program Element at the end of the fiscal year. He will present the data on selections at the next meeting. Regarding facilities, which PSS discussed at several meetings, he would like to give NAS an opportunity to weigh in before taking any actions. The review of the NASA-funded facilities has occurred, and the reports are available online.

Dr. Jani Radebaugh expressed concern that every research topic was covered in the restructuring. Dr. Rall assured her that that was the case. He added that NASA has signed an inter-agency agreement with the U.S. Geological Survey (USGS) that is durable and long-term, and will continue indefinitely with a dedicated funding stream that increases the funding. The three agencies funding the Antarctic Search for Meteorites (ANSMET)—NASA, the Smithsonian Institution, and the National Science Foundation (NSF)—now have a 10-year agreement. Dr. Timothy McCoy said that NASA will pay new costs related to its activities, but will not fund existing NSF facilities.

Dr. McEwen observed that the NAS studies are important to NASA, but the rules for membership seem inconsistent. Dr. Stephen Mackwell of the Universities Space Research Association (USRA) explained that NAS has very specific membership rules, which sometimes make the reviews difficult to staff. NAS tends to be very particular about conflicts of interest and potential influence. Dr. McEwen cited an evident exception, an extended mission committee. Dr. Michael Meyer of PSD explained that that committee addressed the process and not specific funding lines for the extended missions.

Report on Senior Review 2016

Dr. William Knopf provided an update on the recent Senior Review of PSD's extended missions. The review was divided between two panels: Solar System Exploration (SSE), which covered Dawn, the Lunar Reconnaissance Orbiter (LRO), and New Horizons; and the Mars panel, which evaluated the suite of missions focused on the red planet. Scheduling issues precluded having a single panel, but PSD ensured there was sufficient crossover by having Mr. Doug McCuistion chair both, with Drs. Ralph McNutt and Mark Sykes attending both. Dr. McNutt was also the co-chair of the Mars panel, while Dr. Ray Arvidson was co-chair for SSE.

To ensure a level playing field, PSD established set times for each presentation, panel deliberation, call-back, and panel caucus, so that there were 5 hours total for each project. While there was a cap on the number of people projects could bring into the room, there were active WebEx and telecon lines to enable remote participation. This was dropped during panel deliberations, though Headquarters participation was enabled as needed.

Dr. Knopf described the criteria for the excellent, very good, good, fair, and poor ratings, then presented a list of the missions with their grades. The top finding was that "the panel unanimously believes that all (missions) should be approved for extension." Dawn was reviewed twice, as a mission to Ceres and one to Adeona. (The Dawn team also ran late due to mission activities.) The Dawn @ Ceres mission received a Very Good/Good rating, but the Adeona mission only received a Good/Fair grade, the lowest of any. This input then went to PSD, which directed all nine missions to plan for continued operations through Fiscal Year 2018 (FY18), with Dawn to remain at Ceres instead of flying to Adeona. New Horizons is extended to 2021 with a flyby planned for 2019. Final decisions are subject to the budget.

As noted, the preference was for one panel, not two, but schedules precluded that option. Panel members also want a minimum of 2 weeks to review proposals and prepare questions. That was not possible this time, but it is a goal for the future. Based on feedback from the 2014 panel meetings, which were deemed too short and which required a lot of work by email, the final day after each subpanel was set aside for the chair and subpanels to do first reviews. That worked well.

Reviewers felt that more budget guidance was needed, as overguide requests seemed to be focused on getting science completed. At least one project complained about the concept of layered descopes, which were seen as arbitrary. The review is now asking teams to peel off the least valuable or most expendable pieces of the mission until they get to the minimum science to keep the mission going. Dr. Knopf said that there is a tendency to want to do new science rather than repeated confirmation measurements. At the same time, that must be balanced with operational efficiency. The Senior Review did not seek operational efficiencies this time, though he, personally, would like that element included. It can be difficult, but the science leads find a way to get the science done. The panels pushed back, in fact, so there was a grass roots effort to pull in 20 to 30 minutes on operations. It was among the lessons learned, and will be included next time.

The next Senior Review could be 3 years off, should Congress make the change recommended by NAS. While Dr. Knopf had hoped to get the documentation to the panelists 2 weeks before the reviews began,

the panelists in the first teleconference only had 1 and a half weeks. The panelists for the Mars review had more time. Dr. Lisa Gaddis, a PSS member who was on the SSE panel, agreed that they would have liked more time. On the other hand, they only had three missions to review. Dr. Knopf added that the Dawn mission proposal came in late to SSE, with permission.

At the next Senior Review, he wants to start work on the guidelines much earlier. There is no budget target in the guideline narrative, which reflects budget uncertainty. Still, he feels that the process has been improving over time. The face-to-face presentations should have a predefined agenda and a standard format. The panel chair requested a 20-minute presentation on technology status, which was helpful. Dr. Knopf would like to break out budgets to assess how much science or payload funding is actually tied to R&A. The schedule should also consider a Program Planning, Budgeting, and Education (PPBE) submission. Everyone involved liked the idea of having the reviews away from their offices. While teams have been asked to provide opportunities for personnel development beyond mentoring and advancement of people already on their team, they have found this difficult to accomplish. Dr. Knopf noted the emphasis on archiving data in the Planetary Data System (PDS). Other factors included cost-effectiveness. The panels rated the missions separately rather than comparing them.

Because virtually every qualified reviewer is involved in Mars research, the Senior Review devised a novel way of handling conflicts of interest by forming a highly cross-conflicted panel of Mars scientists. This was done in consultation with the NASA General Counsel's Office (GCO). GCO said that the Review was not a procurement action, and the findings help PSD determine how to distribute funding, so conflicted participants were allowed. It was good to have knowledgeable Mars people on the Mars panel, and those who were conflicted on specific missions did not participate in those discussions. Dr. Knopf presented a chart showing which panelists were conflicted with which missions. As this worked well and GCO has approved it, he hopes to use this panel composition strategy in the future. There were some moments of unease, but overall it worked.

GPRAMA

Dr. Rall described the Government Performance and Results Act Modernization Act (GPRAMA). Ms. Jennifer Kearns of SMD provided a brief history of these evaluations. PSS was to make high-level, subjective assessments of PSD's science performance in five criteria, providing examples for each. Members were to review the document that Ms. Doris Daou had sent them prior to the meeting, then add, edit, or delete examples as they saw fit. Items for consideration must have resulted from activity funded in whole or in part by NASA, though they could be from other divisions. NASA has a strong preference for published results. The most important task was to vote on a color-coded rating and provide short explanatory text.

The SMD criteria for GPRAMA voting are as follows:

- Green – Expectations for the research program fully met in context of resources invested.
- Yellow – Some notable or significant shortfalls, but some worthy scientific advancements achieved.
- Red – Major disappointments or shortfalls in scientific outcomes, uncompensated by other unusually positive results.

This is not an advocacy document, nor is it meant to be comprehensive or cover every mission. The final NASA report will include a portion of the PSS evaluation. This report is read by Office of Management and Budget (OMB) staff, Congressional staff, and the general public, and therefore should target the "intelligent layperson," roughly defined as someone with a college education in a non-science field. The 2016 GPRAMA review was to cover Planetary Science research accomplishments in FY16.

Ms. Daou led the discussion and voting for each of the five science areas represented by the following Annual Performance Indicators, or APIs:

API PS-15-1: Demonstrate planned progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact, and evolve.

After discussion about the specific examples that will appear in the PSS report, Dr. Mihaly Horanyi moved that PSS give this API a rating of Green. The vote for Green was unanimous.

API PS-15-2: Demonstrate planned progress in exploring and observing the objects in the solar system to understand how they formed and evolve.

In discussion of the examples, Dr. Rall explained that the process has evolved. PSD once sent PSS a much larger compendium of results, but later determined that they only needed the highest level results. Therefore, the current document of examples is meant to give sufficient content on which to base the PSS vote. The Office of the Chief Financial Officer (CFO) will assist SMD staff in selecting the highest-impact examples for the intended audience of NASA's Annual Performance Report.. Ms. Kearns added that the PSS document will be kept as a reference, and that the Subcommittee was welcome to state its priorities for items to be included in the report..

The vote for Green was unanimous.

API PS-1.5.3: Demonstrate planned progress in exploring and finding locations where life could have existed or could exist today.

The vote for Green was unanimous.

API PS-15-4: Demonstrate planned progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.

In this review, there was a clarification on one example. A couple of others were moved to different sections. The vote for Green was unanimous.

API PS-15-5: Demonstrate planned progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.

Ms. Daou pointed out that a few of the examples in this section applied to the Planetary Defense Coordination Office (PDCO). The vote for Green was unanimous.

As the Subcommittee was ahead of schedule, Dr. Neal reviewed potential findings from the morning's discussion. These would include costs on cubesats. Related to the Senior Review, he had the "peel-the-onion" descopes, the exclusion of operations, and the lack of preparation time. In answer to a question, he explained that Senior Reviews are concerned with new observations from existing missions that are operating beyond their prime missions. Essentially, the mission teams are proposing new science with the same suite of instruments. Some missions have been extended several times. It is a lot of work to conduct these reviews. The 2-year cadence is a Congressional mandate, but the NAS report has led Congressional staff to consider extending that time period, subject to a vote by Congress. All of that is pending.

Dr. Larry Nittler proposed a finding that the top-level funding for each R&A program be released. Dr. Rall replied that R&A is slowly converging on a basic set of information to present annually to PSS. Dr. Neal noted that there would be additional presentations that could result in further findings.

Mars Updates

Dr. Michael Meyer, PSD's Lead Scientist for the Mars Exploration Program (MEP), began the Mars updates by reviewing the large number of MEP-related publications in peer-reviewed journals. He then presented some science highlights.

The Mars Odyssey and Mars Reconnaissance Orbiter (MRO) science highlights addressed the issue of communicating to the public the subtleties of water on Mars. A number of factors affect observations, and there is more science to be done in this area, especially as unexpected results come in. For example, valleys associated with large paleolakes south of the planetary dichotomy boundary provide evidence for periods of global warming that allowed ice to melt and water to flow more recently than during formation of the ancient channels systems on early Mars.. The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission is working with other missions to study the interaction of the solar wind with the upper atmosphere. The Rovers are all still going strong and the Opportunity rover will be going in and out of Endeavour Crater. All six MEP missions that sought extensions from the Senior Review received them.

A number of meetings and workshops have been scheduled, and the Mars 2020 contamination control and planetary protection working group has been formed. The Mars Data Analysis Program (MDAP) received 166 Step-1 proposals; Step-2 proposals are due in late October. There was an explicit call for high-energy neutron detector (HEND) proposals.

SMD management requested the formation of a Contamination Control and Planetary Protection Working Group (CCPPWG), which will provide expert insight into the challenges of achieving stringent levels of organic and biological cleanliness. The Group will look at certain aspects of the sampling system proposed for Mars 2020, and comment on the design prior to the Critical Design Review (CDR), scheduled for February. CCPPWG will continue its work through design and verification, possibly longer. The Planetary Protection Technology Definition Team (PPTDT) will identify options to meet planetary protection goals, determine optimal processes and materials, establish what does not work, and present near-term options that will provide flexibility in the future. This group is tied into the PPO and extends to all planets, not just Mars. Significant questions and mysteries surround Mars. The Recurring Slope Lineae (RSL), methane, life, etc., are issues. MEP wants to learn why Mars lost its atmosphere and whether humans can live on Mars.

Dr. McEwen asked about the Participating Scientist Program for the ExoMars Trace Gas Orbiter. Dr. Meyer said that ESA has put out a call, although Dr. McEwen noted that that announcement came only days before the proposals were due. Some of the questions he listed might have answers in the near future, while others could require dedicated missions. Some issues are more strategic than others. NASA is developing a better sense of the radiation hazards, for example. He thought the most important science discovery from MAVEN thus far has been the measurement of ions flowing in and out of the atmosphere.

Mars 2020

Mr. George Tahu, Program Executive for Mars 2020, spoke next. Mars 2020 is NASA's next strategic mission to Mars. A mission overview showed that many elements, such as the cruise approach, the entry, descent, and landing (EDL), and the surface mission are building on the work done for the Curiosity Rover. An important improvement is new capabilities that will enable smaller landing ellipses. Mars 2020 is also enhancing surface operations productivity in order to maximize the science performed. This includes speeding up the decision timeline for commanding the rover. An area of vulnerability on Curiosity has been the durability of the wheel materials, which will have a new design.

Dr. Ken Farley, Mars 2020 Project Scientist, added that the collection of instruments is new. He singled out the Planetary Instrument for X-ray Lithochemistry (PIXL) and the Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals (SHERLOC) instruments. The RIMFAX ground-penetrating radar will enable analysis of the ground down to tens of meters. The sampling and caching subsystem is new, with elements such as a coring drill and a caching assembly for storing and sealing sample tubes. Inside the caching assembly, a small robotic arm will verify a sample is in the tube, take a picture of it, and seal it. Tubes with samples will go into storage, then be dropped onto ground.

There has been some testing using the Strelley Pool stromatolites found on Earth and determined to be good proxies for the likely geological and biosignature conditions to be encountered by Mars 2020. Dr. Farley presented a graphic depicting eight candidate landing sites. The selected site must provide clear opportunities for safe and efficient exploration and sampling of diverse regions that have high potential to indicate signs of ancient life and planetary evolution. Mars 2020 will not seek signs of existing life and therefore will not explore potential "special regions." It is important to know what investigations will take place before choosing a site, and therefore the team has worked on quantifying the likelihood of meeting the mission objectives at each site.

The Returned Sample Science Board (RSSB) interacts with the Mars science office to address questions. The board has determined the temperature threshold samples can experience without significant science loss during drilling and storage, and considered tradeoffs among alternative strategies for assessing Earth-sourced contamination in returned samples. Regarding assessment of contamination in returned samples, it was determined that the Witness Blank Strategy is adequate for science and much easier for engineering than a drillable substrate. Detailed RSSB reports are available on request.

Dr. Neal asked why drillable substrate was not put forward. Dr. Farley explained that it was thoroughly reviewed. The issue was contamination introduction possibilities, which the witness blank would minimize. The drill bit will be cleaned and sterilized before launch. He further explained that PPS has seen this.

Dr. Neal asked if there is planetary protection plan for Mars 2020 and if it has been approved. Dr. Farley responded that they had Level 1 requirements from the Planetary Protection Office and that they intend to meet those requirements.

Dr. Anbar questioned whether Mars 2020 will have to deal with back contamination concerns. Mr. Tahu added that forward contamination is the concern for Mars 2020, while back contamination will be the issue for a future mission that may return samples. The Jet Propulsion Lab (JPL) has looked at this in both directions. The outbound mission will need to follow the sample return requirements.

Caching will follow the "depot caching" concept, which has been determined best for a retrieval mission. Mars 2020 will drop each tube on the surface, ideally at a single depot site, but the decisions on this are left to the future mission team. The hope was to enable flexibility. Dr. Farley added that extracting samples will be more complex than retrieving them from the surface. Mr. Tahu explained that keeping the tubes in a canister on a Rover would be literally keeping all of the eggs in one basket. It is much simpler for a robotic element to pick up tubes from the ground than it is to reach into another Rover and pull out a canister (in the case of a dead/failed sampling rover before depositing a container of samples). If the robotic arm were to get stuck or otherwise fail, both missions would be losses.

Of the many new wheels being tested, all candidates thus far have outperformed the Mars Science Laboratory (MSL) wheels. There will be a lot of new elements despite the heritage approach. The launch vehicle will be the Atlas V541. Surface operation productivity improvements have been identified,

prioritized, and baselined. A robotic helicopter demonstration is under consideration. Cost performance is going well, and the program is moving ahead. Mr. James Watzin, MEP director, explained that the helicopter would be a technology demonstration, independent of the mission. In response to a question from Dr. Neal regarding how the RSSB interacts with the Mars 2020 project, Dr. Farley noted that the RSSB is an independent group that conducts evaluations as requested.

MEP Update
Mr. Watzin provided an update on the MEP. MEP's operational assets are healthy and productive, and all six missions did well in the Senior Review. The Curiosity and Opportunity rovers, Mars Odyssey, Mars Express, MAVEN, and the Mars Reconnaissance Orbiter (MRO) continue providing good science. Mars 2020 is proceeding well and within budget. International partnerships are integral to the mission's success. However, no new Mars missions have been budgeted or approved beyond 2020. The program is studying next steps and is working to address Decadal Survey science priorities for Mars Sample Return (MSR), provide continued operations on Mars, provide support for the Journey to Mars (J2M), and engage in meaningful partnerships.

MRO is degrading, and one of the orbiters is having reaction wheel issues. Mars Odyssey will be gone soon, as it is under strain, as are other missions. MEP provides support for J2M by studying potential landing sites, identifying and characterizing resources, and assessing returned samples. MEP can also be considered as a precursor to J2M insofar as the experience in operating infrastructure at Mars is valuable, as is the accumulating knowledge of Mars geology, geography, and habitability. J2M continues evolving within NASA. The value of the Mars robotics program to the Earth-independent phase of J2M is becoming increasingly important. With the age and decline of the existing missions, this compounds the schedule urgency for defining the next robotic mission. MEP is anxious to define and lay out the future of the program. It takes time to develop a mission, and costs are higher up front. It is important to avoid a significant gap.

Studies point to the need for a new orbiter, specifically one involving communication relay services, NASA issued an RFI and studied the potential for commercial relay services. All the models examined would require some combination of NASA funding for launch, an early deposit, and a guaranteed subscription/lease arrangement to recoup cost and ensure a reasonable return on investment. MEP recently reviewed Discovery-sized orbiter analogs, such as MAVEN, that demonstrated affordability. Finally, five industry studies are exploring high technology readiness level (TRL) heritage system approaches. In summary, the missions in place are doing great science, and the development programs are on track. Future planning focuses on robotic exploration, which is an important enabler of U.S. leadership in exploration.

Dr. McEwen asked how NASA might use the SpaceX transport system if it lands in 2018. Dr. Watzin said that the Agency is looking at how to leverage any SpaceX success. MSR is perceived as extremely ambitious and costly, so if others can do something NASA can leverage, the Agency has to look at it. There are no future missions approved, which is a challenge. The Agency has initiated some studies but has not yet put together the next Mars program after 2020. There are a lot of considerations, including funding, though complexity is not a big concern – the MEP team thinks they can do this robotically.

Dr. Anbar pointed out that the science payoff for any sample collection is when the samples are returned, and questioned whether there are any specific plans for how samples will be returned from Mars. Mr. Watzin responded that while there are no programs for future missions in the current budget, there are ongoing studies regarding how best to put a program together after Mars 2020.

Dr. McEwen pointed out that at the last PSS telecon, Mr. Watzin said that the next Mars orbiter would be tasked with retrieving the samples. Mr. Watzin responded that that is one concept under consideration.

The rendezvous and docking technologies are not a problem, nor is transfer from one orbiter to another. But the trade spaces and variables are all under study.

Dr. Neal asked how PSS might help. Dr. Watzin replied that MSR is a priority in the Decadal Survey, and while the Mars 2020 mission is the first step, this is a complex undertaking of multiple missions. The success of the program has obscured some of the urgency. Therefore, MEP is pointing out the potential for a gap. An integrated, collaborative effort is best. PSS can help through continued advocacy for the overall objectives, and by continuing to convey the relevance. While the Decadal Survey calls for the intiation of sample return, there is no budget for the next step.

Europa and Icy Worlds

Dr. Curt Niebur, Program Scientist for Europa missions, explained that Europa is considered the most likely place in our Solar System for life beyond Earth.

Europa Flyby (Clipper)

Habitability is believed to require water, nutrients, and energy, and geological activity could bring key evidence to the surface. Although it will not directly search for life, the Europa flyby mission will thoroughly study Europa's habitability. The mission will interrogate plume dynamics, and has the ability to detect smaller ones than those detected thus far.

The acquisition strategy plan is an important step, and the Agency approved the plan in June. JPL will manage the project. The program determined that a laser altimeter would not bring value commensurate with its cost, so that is off the table, as the Clipper is not an orbiter for which altimeters are of greater value. The program is now analyzing costs and schedule elements in preparation for entering Phase B in April. The current plan includes nine instruments. Dr. Niebur showed likely coverage and resolution from the camera suite. Currently, there are areas with no data and other areas of poor resolution; the Clipper will take a huge leap beyond that. It took more than 45 different spacecraft configurations to reach the design that accommodates each instrument. A new challenge is to reduce the number of solar panels.

The science team has met several times; Dr. Niebur reviewed their discussion topics and the covenant they developed to guide the team. One of the significant science topics is "the ladder of life," which ranks criteria from habitability to definitive proof of extant life. The rungs in between need to be fleshed out. A stoplight chart depicted instrument readiness. Every instrument will be on for every flyby. The team has decided to go with solar power because it is possible and because of advances in that area, including hard data on how solar cells will perform in this environment for up to 5 years. The project has gone as far as a procurement award.

Europa Lander

Dr. Niebur told PSS that the team is seeking additional feedback for Europa lander concept studies. Congress is interested, and the team is in pre-Phase A, feasibility assessment. There is now a Science Definition Team (SDT) for the lander, with three mission goals:

1. Search for evidence of biomarkers and/or extant life.
2. Assess the habitability of Europa via in situ technologies unique to a landed mission, not repeating Clipper work.
3. Characterize surface properties at the scale of the lander to support future exploration.

The SDT's requirements are with the engineering team, and a final report is due at the end of November. The team would like as many eyes on this as possible, and has given a summary of the science objectives to the Outer Planets Assessment Group (OPAG) and CAPS. The SDT will brief the community once there is a mature product, and will share the report with PSS.

The SDT has broken out five sub-objectives within the first goal, searching for evidence of biosignatures and signs of life on Europa. To find evidence of life requires broad consensus, so the mission must make sure that the science community agrees on the type of evidence to seek. There is no single way to prove a mission has found life, so it is important that the mission's work not be rejected. NASA has accelerated discourse and investment in this area, including workshops, a possible Centennial Challenge focused on life detectors, expanding the Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) and Maturation of Instruments for Solar System Exploration (MATISSE) programs, and the COLDTech program.

Dr. Ariel Anbar expressed concern about the need to set research priorities in the face of uncertainties about Europa and budget realities. Dr. Niebur replied that the research paradigms must come first. Should the Clipper mission present a better understanding of habitability that would help the efficiency of the lander. However, that is not the opportunity NASA has been given. He wants to be ready to move forward when the opportunity presents itself, and the mission team can draw from the work done on Mars. There have been 83 COLDTech proposals, but he was not at liberty to discuss them yet. The team sees a need to move beyond lab work and instrument development.

The science-enabling mission requirements from the SDT include imaging, sampling, delivery, and sample analysis, all with a model payload that will be about the size of a milk crate. As for programmatic highlights, the pre-Phase A study team has found that they cannot co-manifest with a multiple-flyby mission. In addition, the payload mass capability can be 35 kg, and the mission can have batteries with a 20-day lifetime. For the flight system, the carrier and relay stage will enter orbit and function as a communications relay.

NASA has also studied the issue of landing on undefined terrains, determining that legs can function as stabilizers. These will not be walkers, however. The sampling arm will be sized to retrieve a sample regardless of how far it has to go. The landing system is being developed with the Mars 2020 mission and will use Terrain-Relative Navigation (TRN) to enable a safe landing. Lidar will help identify the safe spots for landing. The most interesting places scientists want to go are often the least accessible, and Dr. Niebur wants to land safely at the most interesting place, which this configuration will allow.

The sampler will likely have a big arm and counter-rotating circular saws that are being tested on rock-like substances. In practice, it should retrieve five samples of at least 5 ml volume. The SDT hopes to learn how water is brought up from the interior. The lander team has a goal of significant autonomy in surface operations, which is part of the reason they want stabilizers. A goal is to undertake measurements after sample retrieval. Any life that is found will probably be microbes, not macro-fauna. The mission will last for 20 days. A key challenge is managing expectations for this mission, and the SDT was challenged to assess the realism of an expectation of a press conference 25 days after landing to announce results of the life detection objective.. The team needs to know as early as possible if that is not achievable.

Dr. Neal asked how PSS can help. Dr. Niebur replied that the team needs help in determining how to vet the approach for searching for life. He liked Dr. Neal's suggestion of bringing in subject matter experts.

Discussion

Dr. John Rummel elaborated on the GHAPS balloon mission, which just went through pre-Phase A. The mission has a 1-meter telescope, and NASA is putting together an AO for instruments. Funding will come from the Discovery futures line. The team has yet to determine how investigators will compete for time. The first flight will be out of Ft. Sumner, NM, in 2019. Dr. Rummel hopes for at least five additional flights, with the possibility of a long-duration opportunity from Antarctica. Dr. Rall added that there is uncovered capacity at field centers that can do this work.

Dr. Louise Prockter of the Lunar Planetary Institute (LPI) explained that LPI is contracted to run two or more multi-year initiatives. Goals of the newest initiative are to look at the first billion years of the solar system by bringing together diverse scientific communities to address knowledge gaps, then promote interdisciplinary research. There will be four topical conferences, with additional sessions and meetings as needed, as well as publications.

Dr. Neal reviewed some preliminary findings, beginning with the growing cubesat requirements and budgets for cubesats. Dr. Timothy Swindle observed that while cubesats cannot be allowed to jeopardize mission success, they do not need to have same requirements as the primary missions. Dr. Horanyi said that it is difficult to ensure that nothing will put the primary mission at risk, and wondered about launching multiple cubesats together instead. Dr. Rall said that the issue seemed to be mixing Class A missions with Class D missions, which could cast the cubesats as a risk that has to be managed. Dr. Neal said that the problem is that while cubesats are a good concept, they may need to match the risk mitigation strategies of larger missions. He liked Dr. Horanyi's suggestion of launching multiple cubesats at once. Dr. Horanyi added that best practices need to be identified and formalized. Dr. Neal thought that could be the finding, that the requirements need to be organized better. Dr. Rall explained that NASA's document NPR 7120.5 enables the tailoring of mission formulation and reviews. The question is whether there is any planetary science to be achieved with smallsats at the $100 million level. Most of what PSD does is at that level. Dr. Neal asked Dr. Horanyi to draft a finding.

The next issue was summary information from the R&A programs. Dr. Rall said it would be good to have a finding requesting the basic information PSD would like. Drs. McCoy and Nittler were to work on this. The finding about descope options for extended missions was deferred until the next day. Dr. Jeffrey Johnson was to draft a finding on the Mars updates, integration, and continuity, including the need to address the pending gap. Dr. Rall noted that the strategy is to align PSD funds with priorities. Study results lead the Division to develop its plans. Stakeholders, including OMB, must agree to the next Mars mission. Dr. Swindle was concerned that MEP's inability to move forward was related to OMB. It might help to formalize the requirements for the plan. Dr. McCoy suggested commending MEP for the Mars 2020 work that is enabling the future missions. Dr. Johnson liked the concept of momentum inherent in that phrasing.

Dr. Neal asked Dr. Anbar to draft a finding for the Europa lander.

Adjourn

Dr. Neal adjourned the meeting for the day at 5:04 p.m.

Friday, September 30, 2016

Agenda Updates and Announcements

Dr. Neal opened the second day of the meeting. PSS would review and finalize their findings that afternoon. A few drafts had come in, and since there was time, he had the Subcommittee take a first look at the finding on MSR.

The draft finding stated that to maintain the momentum established by the MEP, PSS recommends that future mission architectures for the next Mars orbiter and for MSR be actively cultivated by envisioning planning horizons beyond the typical 1-year durations limited by budgetary cycles. In addition, PSS sought timely briefings on continuing and planned trade studies (including domestic and international partnerships) that are relevant to enabling successful planning and execution of these missions. Dr. Harry McSween, who had been unable to participate the previous day, said that he had seen a prototype of the return container at JPL. Dr. Neal noted the need for continuity. When asked, Dr. Meyer replied that he would consider this finding to be useful.

The draft sample analysis lab facilities finding said that PSS commends NASA for responding to community concerns regarding the support of lab facilities, including input from a PSS survey about the status of PI-led labs, by asking NAS to review and report on this issue. The data gathered by PSS will be made available to NAS.

The draft Europa lander finding stated that PSS commends NASA for creating a well-qualified SDT to develop the science case for a potential Europa lander mission focused on life detection. This is an exciting but challenging mission concept, both scientifically and technically. In view of the challenge, PSS is pleased that NASA intends to seek wide community feedback on the SDT's initial science plan. PSS was offering to create a task force to review and comment on this plan when it becomes available near the end of November 2016. A suggestion was to add a positive reference to the COLDTech program.

The draft cubesat finding referenced the need to establish engineering guidelines on how to minimize the risk that ridesharing cubesat-based investigations might pose to the prime mission, while keeping the requirements and hence the cost at a minimum. Development of these guidelines would make ridesharing a more acceptable and possibly more frequent opportunity, and open a new wave of low-cost planetary science investigations using cubesats.

Dr. Mackwell pointed out that this effort should involve a cost-benefit analysis that has not yet been done. The question is whether the scientific benefit of the cubesat overrides the risk to the primary mission. Dr. McEwen said that the program also exists to support new scientists. Dr. Amanda Mainzer urged caution with the language, as a small mission is not necessarily less important or challenging. Dr. Horanyi recommended some additional edits, and Dr. Neal said that PSS would pick it up again later.

In a draft recommendation, PSS was asking PSD to release on an annual basis, at the first meeting of PSS after the completion of selections for a ROSES call, data on funding levels by program, overall selection rates across ROSES, selection rates by adjectival rating across all ROSES programs, funding by keyword, and timeliness of funding release by the NASA Shared Services Center (NSSC) after last the program officer action. In each case, data for previous years, where available, should be provided to the committee for comparison. Dr. Swindle noted that PSS could then seek more in-depth information for particular years as needed. Dr. Neal added that it would help to provide the data to PSS at least a couple of days before the meeting so the members can digest it. He wanted to return to this recommendation later.

Analysis Groups Quick Update and Discussions

The Analysis Group representatives each gave brief updates.

CAPTEM
Dr. McSween described recent activities of the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM). CAPTEM has reorganized its Asteroid Sample subcommittee to allow for curation and allocation of samples from multiple asteroid missions. There will be a new CAPTEM chair in January 2017. Highlights of the Johnson Space Center (JSC) astromaterials effort include curation samples status; mission support, as there are many samples from OSIRIS REx and Hayabusa 2 that need to be analyzed in order to understand contamination that could potentially affect the returned samples as well as public outreach, for which there is great interest.

Dr. McSween summarized a meeting held in March, noting that there is interest in a workshop on lab instruments for OSIRIS REx and Hayabusa 2. CAPTEM anticipates a request to conduct peer review of aspects of the OSIRIS REx curation plan. CAPTEM also reviewed the new microparticle impact curation lab, and members are assessing online catalogs for each collection. The Team received an update on the three-agency agreement for collecting and curating Antarctic meteorites and considered a query from NASA about archiving sample analyses. Dr. McSween noted that if PDS does establish a requirement, only peer reviewed data should be archived. Finally, CAPTEM received a briefing on Japanese Space Agency (JAXA) curation.

A list of concerns began with the impact of possible delays in Discovery and, especially, New Frontiers AOs to potential sample return missions. There is also the issue of continued funding pressure on extraterrestrial materials research, and the AGs' white paper on mission-participating scientists.

Science Nuggets: A continuing question is the lunar impact cataclysm and its timing. Investigators do not always have the right samples, and interpreting data can be tricky. The latest data are proving the continuing value of the Apollo samples. Next is a primordial molecular cloud material in metal-rich carbonaceous chondrites.

Dr. Radebaugh asked about the funding calls for extraterrestrial materials. Dr. McSween said that an example would be a New Frontiers mission to return an asteroid sample, or any mission that will potentially return samples to Earth. CAPTEM is mostly concerned with the flow of future missions.

MAPSIT
The Mapping and Planetary Special Infrastructure Team (MAPSIT) is a new group that Dr. Radebaugh chairs. MAPSIT is concerned with mosaics, geologic maps, derived regional and global data products, and associated geospatial infrastructures. In 2014, PSS recommended that there be a cartography R&A group, and MAPSIT fills that role, representing the planetary science community on data mapping needs. The steering committee reflects the diverse topic areas. There have been a couple of town halls, as well as a data users' workshop and a geological mappers' meeting, in addition to steering committee meetings and work sessions on a strategic plan to identify community needs.

The Team's R&A concerns were presented to the NAS Space Studies Board. Planetary Data Archiving, Restoration, and Tools (PDART) is a strong new tool. There is concern that the program is over-subscribed and underfunded, and there will need to be coordination with the U.S. Geological Survey (USGS). MAPSIT also hopes to see how geologic mapping is doing under R&A. Maps can take a long time to produce, from 3 to 6 years, and it is important to help people understand this timeline and how to best address the field.

MAPSIT will continue reaching out to the community in order to keep data easy to use; maintain

communications with NASA Headquarters; determine various interfaces; communicate with international groups; roll out the strategy plan; and identify gaps. There was a mapping-focused session at the Geological Society of America Annual meeting recently that was well-attended, and MAPSIT has town halls and a community meeting planned in the near future.

Dr. Johnson suggested that MAPSIT give presentations to the other AGs, since it is new. Dr. Radebaugh liked the idea, noting that the group would also send its announcements of activities to the other AGs.

SBAG

Dr. Swindle provided highlights from the Small Bodies Assessment Group (SBAG). SBAG had the following findings:

- The Group is concerned about the cadence of Discovery missions and urges NASA to achieve the DS priority with this program.
- SBAG supports the engagement of the Asteroid Redirect Mission (ARM) with the small bodies community, including the proposed hosted payloads and competitively selected investigation team.
- Additional time and allocation from the Deep Space Network (DSN) did materialize as requested.
- SBAG requests that PSD R&A establish a Rosetta DAP.
- Arecibo is a critical facility with funding that is not sufficiently secure. SBAG urges NASA and NSF to address this situation.

SBAG provides a connection between the community and ARM, and a special action team produced a report on ARM connections to priority small body science. SBAG extends beyond PSD to interact with the human exploration and technology offices at NASA. The next two meetings will take place in January and June of 2017.

OPAG

Dr. McEwen reported that the next two OPAG meetings will be in February and August of 2017. A major challenge is how to keep outer solar system science vibrant during "the Decade of Darkness," a 10-year gap with no data. Dr. McEwen presented findings from the August OPAG meeting, in order of priority:

- Europa lander:
    - The SDT chairs presented a progress report, and OPAG comments are pending. The concern is that the mission goals are high risk, resources could be insufficient, and the mission could be considered a failure.
    - OPAG believes PSD should structure the mission so that it is not considered a failure if there is no detection of life.
    - OPAG also recommends that prior to the AO for instruments, proposers be given sufficient time and resources to develop the technologies.
- Io mission study for the next Decadal Survey (DS):
    - New mission studies are needed to inform the next DS. Io seems the most neglected of the high-priority targets in the outer solar system, with the related New Frontiers AO to occur after 2017. At the same time, there have been recent advances in science and technology related to an Io mission.
- New Frontiers 4 draft AO:
    - OPAG's reaction to the draft AO was generally positive, but noted that the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) power declines too rapidly over time, while Voyager is still going after 40 years.
    - OPAG wants to encourage Enhanced MMRTG (eMMRTG) and is disappointed that it will not be available in time for the New Frontiers AO.
- Roadmaps to Ocean Worlds:

  - This study is making good progress and plans a draft report by the end of this year.
  - Concerns from this study center on funding for fundamental research, technologies, instruments, power sources, and launch capabilities.
- R&A:
  - OPAG remains concerned about specific R&A programs.
  - OPAG wants PSD to release the total budget for each R&A program.
  - OPAG asks that PSD evaluate whether the new R&A structure has gaps that preclude the submission and acceptance of certain good proposals.
- Legacy of Cassini and the Cassini DAP (CDAP):
  - OPAG seeks continuation of CDAP beyond the end of the Cassini mission.
- Ice giants:
  - OPAG is pleased with the progress being made in the pre-DS mission study.
- Participating Scientists:
  - Participating Scientist programs should be a standard feature of future missions.
- Juno:
  - The success of this mission is gratifying, but OPAG is disappointed that there is no Participating Scientist program associated with it.

Dr. Rall said that CDAP will extend beyond the Cassini mission but will cease to have a dedicated budget line as the work is absorbed into core R&A. PSD is aware of the needs here. Dr. Jared Leisner added that CDAP allows Europa comparisons. There is always a place for it in the solicitations. Dr. Grimm sought clarification on the Io Observer finding, noting that other missions were also deferred to New Frontiers 5. Dr. McEwen said that OPAG is not advocating it as a flagship mission, but wants an improved study ready for the next DS.

In answer to a question, Dr. McEwen explained that OPAG and SBAG both include scientists who are interested in Pluto. Regarding the Io report for the next DS, he said that the study for the previous DS was quite deficient and therefore a new study needs to be done. He saw no reason to postpone it. Dr. Radebaugh and others wondered about other studies being outdated. Dr. Neal said it becomes a resources issue. Dr. Mackwell added that the DS studies were never meant to be mission definition studies, but were instead done to determine if a decent amount of science could be done for the associated costs. This is an area where the community needs to think about its goals, as NASA should not be defining the targets. The DS does not get down to the level of the mission details and instruments, so it is important to avoid being overly specific, which may prevent innovative concepts.

MEPAG

Dr. Johnson provided an update of the Mars Exploration Program Analysis Group (MEPAG). Curiosity has been on Mars for 4 years now. The Mars Exploration Rover (MER, also Opportunity) has surpassed 4500 sols of exceptional performance on Mars, equivalent to over 50 nominal 90-sol missions. MRO and Mars Odyssey continue to operate well, and MAVEN recently entered the extended mission phase. NASA is collaborating with ESA on the Mars Express and ExoMars Mars Organic Molecule Analyzer (MOMA). Mars 2020 recently completed Key Decision Point C (KDP-C).

MEPAG committees have be adding members and/or reorganizing. MEPAG released the Mars Water In Situ Resource Utilization Planning study (M-WIP), which examined hypothetical water reserves and engineering needs. The Group updated the terms of reference on its website, along with top discoveries, summaries, and a survey of MEPAG newsletter effectiveness. Other activities included participating in the NAS R&A review, participation in the white paper surveys on participating scientists, and assistance with the HEOMD white paper to the International Space Exploration Coordination Group .

MEPAG is enthusiastic about the extensions resulting from the Senior Review. Dr. Johnson went over some of their upcoming mission activities. MEPAG hopes to initiate some new SAGs in late 2017, possibly the addressing role of small satellites for Mars and polar/ice science, for example. Dr. Meyer noted that MAVEN is being studied to determine its potential value as a relay asset. NASA is now looking at whether it should take on that function or continue only with its full science. That decision is at least a year off.

VEXAG

Dr. Grimm quickly reviewed the activities of the Venus Exploration Analysis Group (VEXAG), then delivered his primary message. He said that the community is fraying at the edges. As no U.S. missions to Venus have launched in 27 years, the VEXAG community remains active in international missions, research, workshops, annual meetings, and mission development. The community is poised for critical advances that would be enabled by Discovery, New Frontiers, or flagship missions. Venus is slowing down, the atmosphere is changing, and there are other significant activities that NASA is not addressing, though ESA is doing some work. The people who started with Magellan are at the top of their career arcs. If NASA were to move forward now, the gap would be well over 30 years. Dr. Grimm encouraged PSD to understand that Venus has important role in understanding much about the solar system and Earth. It is essential to recognize this. The community votes with their feet. While there is a perception that the Venus community does not know what it wants, that is not a standard that other communities face. They just want to do good science. Dr. Radebaugh suggested that VEXAG members convince others that the volcanism of Venus is important by focusing and promoting that fact. Dr. Johnson added that they should point out the work they have done, starting with their goals document.

LEAG

Dr. Samuel Lawrence said that considering that since many of the critical questions in lunar science can only be fully addressed with surface exploration, the Lunar Exploration Analysis Group (LEAG) is seriously concerned about the fact that it has been almost fifty years since the last US mission soft-landed on the Moon. Unfortunately, during the last Discovery call, there were only two proposals for lunar missions. LEAG hopes to organize the community for the next call in order to voice common goals. In 2016, LEAG established a New Views of the Moon 2 committee, which had a workshop with many international participants and excellent student participation. In addition to the 18 chapters discussed at the Houston meeting, three new chapters have since been added to the NVM2 plan. LEAG also reviewed the NASA Strategic Knowledge Gaps (SKG) document. The LEAG technology roadmap draft report will be issued in December.

Science nuggets include the first LRO special issue of Icarus, which included 28 manuscripts covering original research on a range of topics. There will be another volume with even more papers coming up soon, and a special issue on future missions enabled by LRO data. Other nuggets presented included new findings about the nature of the dynamic nanodust cloud enveloping the Moon, additional information about the lunar interior, and hydrogen in lunar mare basalts.

Planetary Protection

Dr. Catherine Conley, NASA's Planetary Protection Officer, explained that the PPO protects other planetary environments along with the Earth environment. This enables sample return science. Dr. Conley noted that NASA and ESA have a joint, half-day tutorial on planetary protection. The two agencies coordinate requirements and guidelines so that they are acceptable to both, meaning that NASA's joint missions with ESA are covered.

PPO wants to ensure that scientists are studying the returned samples they think they are studying and not a life form that originated on Earth and traveled with the sampling mission. Extreme-tolerant microbes

can survive spaceflight and grow in Mars-like conditions, while cleanroom isolates can survive for years on the outside of the International Space Station (ISS). Planetary protection constraints are therefore key to protecting science and other future human activities on Mars.

An international framework for planetary protection has been in force since prior to Sputnik, though it has evolved. NASA follows the framework rather than create its own policy, and the Agency self-enforces compliance. However, NASA does have a planetary protection framework, which Dr. Conley described, along with the relevant documents. NASA recognizes that science investments in study of possible extraterrestrial life forms must not be jeopardized, and Earth must be protected from possible extraterrestrial matter carried here from other planets.

Documentation helps prevent future missions from mistaking Earth matter for foreign matter. Dr. Conley described some of the specific constraints for robotic and human missions. PPO has concerns that Earth life could contaminate Mars, Europa, and Enceladus. At the same time, there is a policy of strict biohazard containment of returned samples. Dr. Conley showed the probabilistic formulation to prevent contamination of icy moons and the formula for determining the number of microbes that could survive an icy body. A risk/benefit analysis proposed in the late 1950s has been confirmed numerous times.

The Committee on Space Research (COSPAR), an international scientific organization, provided a workshop example calculation of contamination of Titan. Options for microbial reduction before launch include heat, though some organisms still survive. Dr. Conley described the approaches NASA has employed in various decades. She stated that the present-day cost of conducting heat work similar to what was done for Viking would be about equal to the cost of one science instrument. The challenges are growing. For example, a Mars Rover creates its own heat, creating potential "induced special regions." The relative humidity needed for growth can exist inside an instrument. For experiments on Mars, a false positive could lead to an entire change in policy, while a false negative is problematic for protecting Earth. A false positive previously created a 20-year gap in Mars exploration, so it is essential to confirm biohazards. Guidelines already exist for that, and are essentially compliance with treaty obligations.

NASA and ESA have been planning for MSR, and life detection considerations have been discussed for some time. Current capabilities are the baseline, though capabilities are also likely to continue improving. Understanding what is needed for Earth safety analysis is what her office works on with ESA, as NASA cannot do this on its own. Community scientists need to make sure it is done right.

Synergies Between PSS and PPS

Dr. Robert Lindberg, PPS Chair, has been on that subcommittee for 7 years, beginning as the designated aerospace engineer. PPS has held joint sessions with the Human Exploration and Operations Committee (HEOC) and is interesting in doing so with PSS as well.

Both forward and back planetary protection are inextricably linked to the science. Concerns include microbial contamination and organics, as the presence of organics can create problems for some of the science. After the Viking mission, Mars was viewed as colder and drier than initially thought, but it now proves to be warmer and wetter than once believed. There is a new era of confirmed liquid water flowing on Mars. The subsurface of Mars is a "special region." To explore a special region, missions will have to move back to the system-level sterilization of Viking. Dr. Lindberg agreed with Dr. Conley's rough estimate of the likely costs of sterilization being equal to that of a single science instrument. NASA will need to develop both sterilization technologies and instruments that will survive those technologies.

There are also regulatory issues. NASA has self-regulated with regard to internal policies aligned with COSPAR. However, the return of samples to Earth is not something NASA can decide on and approve in a vacuum. It will inevitably be a multi-agency process to determine the safety of returning samples from

Mars. This should be considered at the front end, including the outbound Mars 2020 mission, in order to avoid opposition later on.

Dr. Neal observed that this discussion affects the science quite markedly. There needs to be a dialogue, and the community cannot afford to have an adversarial relationship here. Planetary science wants to get samples back from Mars, explore Enceladus, and more. To have a definitive positive result will be transformational.

Discussion

Dr. McSween wanted to focus on MSR. NASA has about 95 samples that have been returned from Mars inadvertently (meteorites), and these have not shown evidence for life. Dr. Conley said that there are signs of Earth life on all of those meteorites. Dr. Lindberg added that the lack of ability to get a result is what they are trying to prevent. Dr. Anbar noted the difficulty in keeping samples pristine, which is a science issue. He asked about the state of technology investment in ensuring sealed and pure samples. Dr. Conley said that that is outside her purview, as it is enabling missions. Dr. Lindberg added that PPS advocates for increased funding in this area, for sterilization methods that current technologies can withstand, and new technologies that can withstand more intense sterilization methods.

Dr. Meyer said that MEP has established a planetary protection technology definition team that is looking at what might be possible in drawing from medical technologies, for example. It will also generate a ROSES call. Money is being applied to planning activities leading to future investments. Mars 2020 has specific spending for planetary protection and is developing a sampling system with rigorous cleanliness. A working group on contamination control is looking at the system to see if they can help and assess the ability to meet Level 1 requirements. Dry heat sterilization of current technologies would lead to off-gassing, which would violate organic contamination controls.

Dr. Anbar said that heat sterilization would affect organics. Dr. Conley noted that anything brought back to Earth must be moved out of the tubes in a clean fashion. Dr. McEwen corrected the statement about "confirmed liquid water on Mars," explaining that something flows down slopes, but it is not necessarily water. In addition, there are no good candidates in Gale Crater. Dr. Conley said that there are many dark streaks in the crater, and a single streak with progressing behavior could be a matter of concern for the PPO. Dr. McEwen stated that his definition for RSLs included not only growth but fading and seasonality. She and Dr. McEwen agreed that the status cannot be proven at this point. Dr. Neal wondered if this was the conversation that should take place between PSS and PPS. They need to work together to get the samples back, decide how to do that within the international treaties, and determine how best to do the science.

Dr. Conley said that all dark streaks are special regions under COSPAR. Analysis of the samples on-site is very expensive, and engineering hardware functions differently in varied environments, an example being ISS microscopes that do not work on Earth. There are also human factors considerations. Dr. Lindberg wondered if it really is feasible to bring samples back to cis-lunar space without knowing how to demonstrate that they will not impact Earth. Dr. McSween said that the organic geochemistry community has often said that we will never launch a spacecraft or sampling device that is completely clean. Our ability to analyze small amounts of organic matter will always exceed our ability to fully eliminate it. The object is to reduce contamination to the lowest possible level and also know what was launched. If the goal is to prevent contaminated sample return, we will never bring back samples. Dr. Conley agreed. This is where the regulatory agencies come in, as this is not just up to NASA. The Agency needs to explain what abilities it has, and have those conversations soon.

Dr. Meyer expressed concern about the perception that NASA must worry about all of the dark streaks on Mars. These are geological formations. He felt the definition was too broad. Dr. Conley replied that the

mission team must demonstrate that what they want to do is acceptable. Dr. Lindberg said that many missions have satisfied planetary protection requirements prior to launch. Planetary protection is something that needs to be addressed in daily operations. PPS made a recommendation about acknowledging this as a gap, and the SMD Associate Administrator took it forward, which means there is now daily consideration of planetary protection in Mars operations. This should be a standard for future surface missions on Mars.

Dr. Johnson asked for clarification on the difference between a special region and an induced special region caused by a rover. Dr. Lindberg said that an induced special region could cause water to become liquid and stay liquid for a while on the surface, possibly affecting the science of the current and future missions. The Mars surface is not much of an issue; Europa and Enceladus will be a much more interesting conversation in that regard. However, the question of caves remains, including the scale inherent in the definition of a cave. Dr. Conley said that PPO has had many discussions with the outer planets mission teams, and they have embraced the training she referred to. They are developing some interesting concepts as a result. Dr. McSween asked about the definition of special regions. Dr. Conley said that the parameters change as more becomes known. For example, recent data indicate that fungi can survive at lower water levels than understood previously, so that number could change. The COSPAR standard continues to change, with a margin. Dr. Radebaugh wondered about cleanliness of sample containers to prevent contamination with Earth life. Dr. Lindberg replied that that is an ongoing issue.

Dr. Neal asked about next steps to ensure that science can be achieved while enabling planetary protection in both directions. Communication seems to be key, and everyone seems to want to get the science done and fulfill planetary protection requirements. Dr. Lindberg agreed that the two communities are not that far apart. But there is ample room to explore better ways of doing things.

Dr. Meyer expressed concern about induced special regions, which must be addressed without preventing scientific investigation. In addition, the larger science community should discuss deliquescence in order to close the knowledge gaps. Dr. Conley said that there is a need to understand what might have been introduced by existing missions. This will call for modeling and assessment of what those organisms might have done and might have become. With deliquescence, the high-salt brines are less of an issue than the cycling. Factors include the scale of the special region, and whether water evaporates, after which it turns to vapor and, potentially, frost. Modeling will provide more information about these possibilities. Dr. Neal thought that the concept of induced special regions is ephemeral. The modeling needs to be done to determine if it is, in fact, an issue. Dr. McEwen was concerned that there might not be an acceptable standard to come out of modeling.

Dr. Conley said that she needs data that she has previously requested; those data have not yet been provided to her, however. There are boundaries that can be put on a modeling problem. Dr. Lindberg added that they can look at how these issues affect the quality of the science on both outbound and inbound missions, as well as any biocontaminants that may enter. There should be a logical chain toward reaching the answer. Dr. Meyer wondered how to frame the question in order to give the engineers some parameters. Dr. Neal said that PSS would discuss findings later in the meeting.

Participating Scientists

Dr. Prockter said that the study of the value of the Participating Scientist program was originated by OPAG and supported by other AGs and by PSS. The charge is to evaluate Participating Scientist programs in terms of the value added, the uniformities and differences, and how to maximize the usefulness to the programs. The study team will present the findings to the AGs and write a white paper. The Phase 1 survey went to current or past participating scientists, as well as interested individuals, and had three sections: questions for past or current participating scientists and guest investigators; questions for the entire community; and broad demographic information. The study team distributed the survey

through LPI and PSI newsletters, along with AG mailing lists. This survey is complete. Phase 2 is ongoing, with another survey that asks PIs and project scientists about their missions. Contact has been via email and phone, as well as in person.

Dr. Prockter showed the Phase 1 questions, which asked participating scientists about career phase, the Key Decision Point (KDP) phase at which they entered the project, the activities they were involved in, any involvement in operations, whether they felt they were part of the team, funding, what they did and did not like about the experience, perceptions of the program, and basic level of educational and career attainment. Phase 2 questions, which were sent to mission PIs, ask whether the mission had participating scientists, perceptions of how well it worked, challenges, and how the program might work better.

Around 200 individuals responded to Phase 1; of these, about 120 were current or former participating scientists. A social scientist analyzed the responses and identified some themes. Phase 2 is still collecting data. All responses are anonymous. The social scientist did not help write the questions but did consider them effective. Dr. Prockter would like to have this person involved earlier for any future surveys.

Based on Phase 1 results, respondents uniformly perceive the program as valuable, providing intellectual diversity, expertise throughout the mission, increased science return, and workforce development. Respondents also commented on the personal value of collaboration, data access, experience of mission team involvement, personal career development, and development of skills for future mission leadership. There was a huge range of valuable experience beyond the opportunity to do good science. There is still a wide perception of mission leadership as "an old-boys' club." Many participants emphasized the value to science that diversity brings in fostering innovation and pushing boundaries. The survey found that participating scientists come from across all career levels, and over half have been selected more than once, thus contributing experience.

Many respondents felt it would be useful to come onto the mission early. Longer missions are likely to bring in more participating scientists, however. About one third came in during the cruise phase, and about 60 percent had involvement in operations. Most respondents felt like they were integrated into the team, though it often took a while. Issues included leadership, coming on board, assignments outside their original areas, and level of involvement. On the other hand, some participating scientists eventually became co-investigators (co-Is). At least 90 percent eventually felt they were part of the team. An equal percentage thought they had adequate funding. There was sometimes uncertainty about the length of the assignment, and some participants had to re-propose.

The overwhelming message is that the programs provide significant value, but a more consistent approach would help. In addition, 87.5 percent would reapply to do this again. The preliminary input from the mission leads indicate that they agree that participating scientists add value, but PIs are sometimes protective of their teams and see participating scientists as disruptive. They would like to have input into the selection process.

Preliminary recommendations are that the program is valuable and should be included on every planetary mission. The funding and timing should be clearer. The scientists should be brought on as early as feasible. Those selected later on a mission should be assisted in team integration and training. Funding and expectations should be clearly communicated. Next steps are to finish the survey, present to the AGs and other groups, and write a white paper.

Deep Space Network (DSN) Update

Mr. Pete Vrotsos, Space Communications and Navigation (SCaN) Deputy Program Manager for Network Operations, addressed a PSS finding from the spring meeting. Following a performance dip, the Deep Space Network (DSN) examined a 3-month period in detail but did not detect any systemic issue of

increasing mission data loss. The FY16 appropriations cut to the DSN was 3.8 percent, not the 10 percent figure that was previously reported. Regardless, DSN never cuts anything affecting day-to day operations or maintenance. If necessary, the Network will defer obsolescence activities. Most of the problems that occurred were with the newest antenna in Canberra, Australia, during the third week of January. This was the first newly built antenna in 10 years, with parts provided by multiple suppliers with new suppliers. There was one site-wide anomaly in Canberra for the local area network (LAN). DSN met all L1, L2, and L3 mission-critical events from 2011 to 2016.

DSN's requirement is to capture 95 percent of the science data. From August 2015 to August 2016, DSN serviced 37 missions with 98.6 percent proficiency. A graph showed the one drop-off. For a single researcher with one bad day, that is significant, so DSN is very attuned to each individual track. For Cassini, 5 of the last 6 months had performance of 95 percent or better. There were other missions affected by the Canberra anomaly. The episode has raised questions about maintenance. DSN tries to do major maintenance on each antenna every 18 to 24 months. There is also weekly maintenance. Changes directed at reducing the need and time for maintenance provide more connection time for each device. DSN will delay maintenance activities for major events.

The plan of the DSN Aperture Enhancement Project (DAEP) is to build six additional antennas, resulting in a net increase of antennas as old antennas are decommissioned. All the new antennas are funded through SCaN in-guide budget efficiencies; no overguide funding has been provided for these new antennas. The program is doing more facility work in Spain, with significant participation by the Spanish government. The final two antennas will depend on demand. The plan is to build in the ability to array more 34-meter antennas. A recent program implementation review (PIR) found exemplary success and good ability to manage dwindling budgets. SCaN has requested that the DSN go a layer deeper and do a 90-day study to assess its long-term obsolescence and sustainment plan, its focus, and priorities. The status of missions and connections is always available online.

Dr. Anne Verbiscer asked about the impact of decommissioning Station 45. Mr. Vrotsos said that it was part of the overall plan in funding the antennae, which is within guidelines with no additional funds. A look at the operations side found many inefficiencies. As new assets come online, DSN will be retiring certain assets with high maintenance costs. There will still be excess capacity, however. Dr. Verbiscer expressed concern about the configuration in Canberra, pointing out that there are missions that would benefit from a different antenna suite.

Mr. Vrotsos explained that proficiency evaluations reflect a schedule service to missions. Weather-related events, such as high winds requiring stowage of antennae, are taken out of such evaluations. Such events are infrequent, however. There are measurements at the sites, which he could provide on request. Dr. Radebaugh asked about the software anomaly and asked if PSS could help. Mr. Vrotsos said that power distribution systems have been updated, and he could provide more data about the LAN issue.

Extended Missions Report

Dr. Victoria Hamilton of the Southwest Research Institute (SwRI) presented the extended missions report. The task was to assess the overall value of extended missions, looking specifically at the science benefits of mission extensions, the senior review process and cadence, whether the balance of new and extended missions provides the best science return to NASA, and possible innovative cost reduction approaches. The committee met in person three times, spoke with Congressional and NASA staff, met with senior review and mission teams, and held a committee writing session.

The committee found extended mission science to be productive and valuable. LRO and the Mars Rovers have been particularly successful despite being targeted for cost cuts. Extended mission science is a bargain. Three-quarters of all NASA science missions currently flying are in extended phase, and yet they

account for only about 12 percent of the SMD budget. In some divisions, there are significant integrations among the flying missions. For example, the Heliophysics Division (HPD) considers its missions to be an integrated fleet. The bottom line is that many extended missions make important discoveries, providing long-term and baseline datasets and helping to achieve the science objectives of the Decadal Surveys.

The committee recommends that SMD policy documents formally articulate the intent to maximize science return through extended missions. SMD should also support a robust portfolio of extended science missions. If a Senior Review recommends termination due to funding limitations, NASA should allow the mission team to re-propose with a different approach.

Another recommendation is to conduct Senior Reviews on a 3-year cadence, which would require Congress to enact a change to the current law. Congressional staff members are open to this, provided the technology/operations evaluation processes are ongoing. There are multiple justifications for a 3-year cadence. For example, it takes mission teams up to 6 months to prepare a proposal for a 2-year mission extension, which takes time away from conducting the science. Less frequent reviews might make it easier to recruit panelists. This is also a significant effort on NASA's part, so a 3-year cadence will cost less and be less of a burden on staff. Finally, the prediction for 3-year reliability is about that of the 2-year reviews. At the 4-year mark, there could be changes in the science, however. The bottom line is that the committee believes NASA will get more value from a 3-year cadence. It will be helpful to offer division directors some flexibility to accommodate mission dates and other events.

Regarding proposals, the committee heard that across the divisions there is different emphasis placed on new science versus continuity. NASA should also encourage extended missions that target national needs like space weather and expand beyond the original missions. In terms of the review panels, the committee heard that the timeline was too compressed, and sufficient time should be set aside for all aspects of the review. The reviewers are volunteers and should not have compressed workloads. The panels should have a good mix of senior scientists, some continuity from other reviews, and some early career people. SMD should continue to encourage the sharing of best practices for Senior Reviews. Finally, the guidelines should state the intention to solicit feedback on the process in order to enable continued improvement.

In the area of funding, NASA should anticipate extended missions and provide appropriate resources. Emphasis should be on the scientific importance of extended missions, with cuts leveling off instead of continuing to deepen. The Agency should also ensure that there are open communications among missions so that best practices are known, and assess and accept increased risk for extended missions on a case-by-case basis.

In answer to a question, Dr. Hamilton explained that the four science divisions have roughly the same percentage of funds set aside for extended missions.

Findings and Recommendations Discussions

Discussion for Dr. Prockter's presentation had been deferred for this session as the data-gathering process was still ongoing. Dr. Johnson asked if the survey had separated out the non-NASA participating scientists. She replied that some questions did not apply to them, but they were not screened out. The contact lists were unlikely to include many such people, however. Regarding competed and directed participating scientist positions, Dr. Prockter was not certain but recalled that they all thought it was positive. There are still some uncertainties with the Phase 2 survey being out. The basic message thus far is to have more communication, which may mean clearer direction from R&A. Dr. Neal said that PSS would wait for the white paper.

Turning to DSN, Dr. Neal said that what distressed him was the dwindling budgets. This is extremely important work, and he wanted to know how PSS could help. Mr. Vrotsos replied that the overall SCaN

budget has gone down. Maintaining the DSN operations budget comes at the expense of enabling advanced communication technology. The top priority is to service the missions. Dr. Neal said that DSN impacts a lot of planetary science, and its aging network can create only so many efficiencies. Nobody wants to risk hitting the downslope. PSS should highlight this for those who can push on it. He cautioned that it was important to specify the performance rate and not be prescriptive, however.

One suggestion was to note what is not being supported. Mr. Vrotsos said that another point is that the increasing number of active and extended missions is pushing up against the finite capacity of the assets in DSN's suite. Information regarding the percentage of extended mission relying on the DSN can be provided. At present, DSN can meet the minimum science requirements from all of the requested passes. Data are scheduled, leaving some additional time. Missions must match Earth's rotation and the antennae locations. DSN is not at maximum capability, and he does not believe anyone in the Agency wants the network to get to the breaking point.

Dr. Swindle asked if it was time to worry, and Dr. Neal again asked how PSS might help. Mr. Vrotsos said that the catastrophic failures have been elevation-bearing failures. The design has a lot of margin. This issue is more about antiquation than risk of failure. Mr. Phil Liebrecht Deputy Program Manager for SCaN said that good engineers are looking at this and do not believe a collapse is likely. The array of 34-meter antennae buys DSN some robustness. It was noted that some – but not all – spacecraft have storage for data, but operating them longer may become a factor. In addition, the mission PIs could try to help DSN if they knew more about what was going on. Mr. Vrotsos said that DSN has an annual meeting it could publicize more to its customer base. Mr. Liebrecht emphasized the importance of awareness of the role of NASA's space communication networks in the success of all NASA missions.

Dr. Neal moved on to other issues. He wanted to mention Dr. Hamilton's impressive report in the meeting letter. He next had Dr. McSween read a proposed finding about the planetary protection discussion. The first draft of this finding stated that the PPO concept of "induced special regions" on Mars requires a comprehensive discussion to ascertain the significance of this issue. This potentially has consequences for landing site selection, lander and Rover operations, and sample return. PSS and PPS should organize a workshop of experts to assess whether landers or Rovers could actually produce a local environment that would be heated and contain aqueous fluids that have sufficiently high water activity and that could persist long enough to plausibly harbor life, and whether this should prevent further exploration of this site and the return of samples from the vicinity.

Dr. Meyer reiterated his concern about induced special regions, and Dr. Conley reminded him that she has requested from MEP analyses that she must have in order to move the discussion along. This could answer many of the questions in front of PSS. Depending on local conditions the rover would encounter, it might dictate where rovers might and might not go and/or land. Dr. Meyer said that Mars 2020 understands that, but Curiosity does not seem to have it as a priority. Dr. Conley said that, given the conditions of Gale Crater, it was possible that Curiosity was creating an induced special region. She thought it was unlikely, but she could not be certain and still needed the data that the Mars program agreed to provide her.

Dr. McSween said that this would be a priority for the Mars 2020 team, which would not want to probe an induced special region. Dr. Conley suggested having a more thorough discussion of special regions. Dr. Neal said that he understood the concern that induced special regions might promote the growth of rover-carried microbes. Dr. Conley offered to share a paper about microbes in Chile's Atacama Desert. She was uncomfortable with assertions that microbial growth could not happen on Mars.

Dr. Neal said that he was hearing Dr. Conley say there should be an analysis first, and Dr. Meyer say there should be a workshop first. He would like to have PSD, PPO, and additional experts examine and

evaluate the risk in order to move closer to resolution. Dr. Conley suggested including astrobiologists. The cost comparisons for sterilization have been done, and it is possible to build hardware that will tolerate the process. She would like to address all contingencies, though Dr. Neal cautioned that that might be more than they can do. He said that PSS would revise the draft finding to reflect discussion, then send it to members for comment.

Dr. Grimm asked if there is a way that data acquisition can be more automated and science teams decreased on some of the extended missions. Dr. Neal said that that is up to the Senior Reviews, which consider it. Dr. Meyer added that there are specific recommendations to reduce funds to certain parts of a mission.

Dr. Gaddis wrote a finding about the extended missions study. The draft stated that PSS appreciates the report on extended missions and supports the general finding that extended missions are good value for NASA. PSS especially supports the report's recommendations for a flexible, 3-year review cadence for Senior Reviews and on the need to give panels additional time to review proposals, conduct the review, and prepare a final summary of findings. The recommended 8 weeks between receiving the proposal and the review panel meeting is appropriate.

Dr. Grimm remained concerned about Senior Reviews. Dr. Neal replied that the Senior Reviews in which he has been involved have made descope recommendations, as appropriate. Dr. Johnson asked that the draft finding mention the need to balance science and operations in the reviews. Science is most important. Dr. Gaddis agreed to add a point about science flexibility.

Dr. Verbiscer's draft finding on DSN stated that PSS is concerned that plans to decommission 34-m stations in Canberra and Goldstone will remove any backup to the aging 70-m stations that are essential for communication with NASA's most distant assets in the solar system, such as Voyager and New Horizons. This concern is amplified by budget cuts to DSN. New Horizons in particular, now in extended mission to encounter a Kuiper Belt object in 2019, has its longest view periods at Canberra, where the 34-m station that is scheduled to be decommissioned will not be replaced until 2022, after the New Horizons extended mission ends. Furthermore, decommissioning stations before replacements come online places additional stress on an already highly subscribed network. PSS supports requiring DSN to keep four 34-m stations online at Goldstone and Canberra as backup to the critical 70-m stations.

Dr. McCoy said that the last sentence disturbed him, since the costs are unknown. Dr. Grimm suggested a generic statement on keeping capabilities at a certain level. Dr. Verbiscer replied that the point is that it is premature to decommission. She noted that Mr. Vrotsos said that no one had asked them to keep it online. Dr. Swindle suggested asking for cost data, which Dr. Neal took as an action. Dr. Johnson asked that the finding begin on a more positive note, stating something like PSS is impressed with the rate of performance and wants to keep that standard. Dr. Verbiscer deferred to Dr. Neal's edits.

Dr. Neal stated for the record that PSS members should stay for the full 2-day meetings going forward. He noted that several had already left. He planned to collate the meeting findings and send them to Ms. Daou. There will be a finding on Dr. Hamilton's survey after the full report, and he wanted to promote the idea of the combined PSS/PPS workshop.

Dr. Rall planned to conduct a poll and find a time for the next meeting, probably in the late winter/early spring timeframe.

Adjourn

The meeting was adjourned at 4:30 p.m.

Appendix A
Attendees

Subcommittee members
Clive R. Neal, University of Notre Dame, *Chair, Planetary Science Subcommittee*
Jonathan Rall, NASA, *Executive Secretary*
Ariel Anbar, Arizona State University
Lisa Gaddis, U.S. Geological Survey
Robert Grimm, Southwest Research Institute
Mihaly Horanyi, University of Colorado
Jeffrey Johnson, Johns Hopkins University
Samuel Lawrence, Johnson Space Center
Amanda Mainzer, Jet Propulsion Lab *via teleconference*
Timothy McCoy, Smithsonian Institution
Alfred McEwen, University of Arizona
Harry McSween, University of Tennessee
Larry Nittler, Carnegie Institution of Washington
Jani Radebaugh, Brigham Young University
James Skinner, Jr., U.S. Geological Survey
Timothy Swindle, University of Arizona
Anne Verbiscer, University of Virginia

NASA attendees
Barbara Adde, NASA HQ
Charlie Bonner, NASA HQ
Laurie Cantillo, NASA HQ
Catherine Conley, NASA HQ
Doris Daou, NASA HQ
Elaine Denning, NASA HQ
Chris Fitzsimmons, NASA HQ
Jeffrey Hollingsworth, NASA
Jennifer Kearns, NASA HQ
William Knopf, NASA HQ
Brook Lakew, NASA GSFC
Jared Leisner, NASA HQ
Phil Liebrecht, NASA HQ
Michael Meyer, NASA HQ
Curt Niebur, NASA HQ
Sarah Noble, NASA HQ
Christina Richey, NASA HQ
Tom Statler, NASA HQ
George Tahu, NASA HQ
Megan Thompson, NASA HQ
Peter Vrotsos, NASA HQ
Jim Watzin, NASA HQ
Melissa Wichenshier, NASA HQ
Jim Wilson, NASA HQ

Non-NASA attendees
Alice Bowman, Applied Physics Lab
Robert Lindberg, University of Virginia
Steve Mackwell, USRA
Louise Prockter, LPI
Elizabeth Sheley, Ingenicomm

J. Andy Spry, SETI Institute
Ana Wilson, Ingenicomm
Helene Winters, Applied Physics Lab

WebEx participants
Brent Archinal, U.S. Geological Survey
Richard Bondrak
Ben Bussey
Jason Callahan
Nancy Chanover
Michael DiBiasi
Casey Dreier
David Eisenman
Ken Farley
Jimmy Fogert
Marc Fries
Kevin Gilligan
Jeff Grossman
Vicky Hamilton
Kirk Hamm
Grace Hsu
Doug Isbell
Michael Kaplan
Jennifer Kearns
John Keller
Erin Kennedy
Gilbert Kirkham
Robert Lindbert
James Lochner
Emily Lakdwala
Noah Petro
Betsy Pugel
Christina Richey
John Rummel, East Carolina University
Kurt Rutherford
Nick Saab
Daniel Singleton
Mike Skrutskie
Tommy Thompson
Galen Watts
Alexandra Witze

Appendix B
Membership Roster

Clive R. Neal, Acting Chair
University of Notre Dame

Jonathan A. R. Rall, Executive Secretary
Planetary Science Division
Science Mission Directorate
NASA

Ariel D. Anbar
Arizona State University

Lisa Gaddis
Astrogeology Science Center
U.S. Geological Survey

Lori S. Glaze
NASA Goddard Space Flight Center

Robert Grimm
Department of Space Studies
Southwest Research Institute

Candice Hansen-Koharcheck
Planetary Science Institute

Mihaly Horanyi
Laboratory for Atmospheric and Space Physics
and Department of Physics
University of Colorado

Jeffrey R. Johnson
Applied Physics Laboratory
Johns Hopkins University

Samuel Lawrence
NASA Johnson Space Center

Amanda Mainzer
Jet Propulsion Laboratory

Timothy McCoy
Department of Mineral Sciences
Smithsonian Institution

Alfred S. McEwen

University of Arizona

Harry McSween
Department of Earth and Planetary Sciences
University of Tennessee

Larry Nittler
Carnegie Institution of Washington

Lisa M. Pratt
Indiana University

Jani Radebaugh
Department of Geological Sciences
Brigham Young University

James Albert Skinner, Jr.
U.S. Geological Survey

Timothy D. Swindle
University of Arizona

Anne Verbiscer
University of Virginia

Appendix C
Presentations

1. *Planetary Science Division Status Report*, Jonathan Rall
2. *Research and Analysis Program,* Jonathan Rall
3. *Briefing to PSS on 2016 Planetary Mission Senior Review (PMSR),* William Knopf
4. *FY16 Planetary Science GPRAMA Performance Assessment*, Jennifer Kearns
5. *Mars Exploration Program Science Highlights, Status, Updates*, Michael Meyer
6. *Mars 2020 Status Update*, George Tahu, Ken Farley
7. *Mars Exploration Program Update*, James Watzin
8. *Europa Missions Status*, Curt Neibur
9. *CAPTEM Report to the Planetary Science Subcommittee*, Harry McSween
10. *Mapping and Planetary Spatial Infrastructure Team*, Jani Radebaugh
11. *Report from the Small Bodies Assessment Group (SBAG) to the Planetary Science Subcommittee*, Timothy Swindle
12. *Outer Planets Assessment Group (OPAG) Report to PSS*, Alfred McEwen
13. *MEPAG Report to PSS*, Jeffrey Johnson
14. *VEXAG Update*, Robert Grimm
15. *Lunar Exploration Analysis Group Report to the Planetary Science Subcommittee*, Samuel Lawrence
16. *Planetary Protection Overview*, Catherine Conley
17. *White paper on the value of Participating Scientist programs to NASA: Progress report to PSS*, Louise Prockter
18. *Deep Space Network Update*, Pete Vrotsos
19. *Extending Science – NASA's Space Science Mission Extensions and the Senior Review Process*, Victoria Hamilton

Appendix D
Planetary Science Subcommittee Meeting
September 29 and 30, 2016
NASA Headquarters
Washington D.C.

Thursday, September 29, 2016, 8:30 a.m. – 5:00 p.m. (5H41)

08:30	Welcome, Agenda, Announcements	(C. Neal, J. Rall)
08:40	PSD & R&A Status + Findings Update	(J. Rall)
10:00	Break	
10:15	Report on Senior Review 2016	(B. Knopf)
10:45	GPRA-MA	(J. Kearns/All)
12:30	Lunch	
1:30	Mars Updates	(J. Watzin/ M. Meyer /G.Tahu/K.Farley)
3:00	Break	
3:15	Europa and Icy Worlds	(C. Niebur)
3:45	Discussion	(All)
5:00	Adjourn	

Friday, September 30, 2016, 8:30 a.m. - 5:00 p.m. (5H41)

8:30	Agenda Updates & Announcements	(C. Neal, J. Rall)
9:00	Analysis Groups Quick Update and Discussions	(10 mins each)
10:30	Break	
10:45	Planetary Protection	(C. Conley)
11:15	Synergies Between the PSS and PPS	(R. Lindberg)
11:45	Discussion	(All)
12:30	Lunch	
1:30	Participating Scientists	(L. Prockter)
2:00	DSN Updated	(P. Vrotsos)
2:30	Extended Missions Report	(V. Hamilton)
3:00	Findings and Recommendations Discussions	(All)
5:00	Adjourn	