NASA ADVISORY COUNCIL

Planetary Science Advisory Committee

February 21-23, 2018

NASA Headquarters
Washington, D.C.

MEETING MINUTES

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Dr. Anne Verbiscer, Chair

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Dr. Jonathan Rall, Executive Secretary

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Wednesday, February 21, 2018

Opening, Announcements

Dr. Jonathan Rall, Executive Secretary of the Planetary Science Advisory Committee (PAC) of the NASA Advisory Committee (NAC), opened the meeting. This was the first meeting since the Planetary Science Subcommittee (PSS) transitioned into a full advisory committee. He noted that in its new format, the group was experimenting with not having the Assessment Group (AG) chairs serve as Committee members. Dr. Anne Verbiscer, PAC Chair, then welcomed the members.

Following the mandatory government ethics training session, Dr. Rall explained that PAC advises NASA's Planetary Science Division (PSD). The advisory committee structure allows PSD to hear from the Committee directly. Dr. Rall then asked the PAC members to introduce themselves and state their areas of expertise.

Welcome from Division Director

Dr. James Green, Division Director for PSD, welcomed the PAC members. He expects the Committee to be very tactical. This is the golden age of planetary science, with a significantly improved budget for PSD. There had been huge budget cuts in 2012 and 2013, but that funding has been replaced, along with new initiatives. Since the overarching strategies are laid out in the Decadal Survey (DS), PAC will be more concerned with execution, especially in light of upcoming opportunities to enhance the program. Dr. Green anticipates that each PAC meeting will address a particular charge. PSD is open for input, as this is the community's program.

He believes the budget has improved for a number of reasons, first among them that the community has rallied around the DS and has executed it in a way that has been noticed. There are challenges and some difficult missions coming up. Planetary science is hard, Mars science is hard, and he always worries about landings. The Interior Structure from Seismic Investigations, Geodesy and Heat Transport (InSight) will be one of those missions, launching from the Vandenburg Air Force Base in California in a few months. Future efforts include the Mars 2020 mission and a suite of New Frontiers and Discovery missions.

This meeting's focus was to be on how to leverage the Research and Analysis (R&A) Program in order to identify and execute high-risk, high-reward (HR2) proposals. This has been a topic for all of the Science Mission Directorate (SMD) divisions' advisory committees. While PSD already has an approach to HR2 proposals, it turns out that each science division handles them differently, and SMD management decided to seek community input in order to have a more consistent approach. Primarily, SMD wants to determine how to identify and fund some of these proposals. The PSD R&A Program is healthy. Dr. Green would prefer a higher selection rate, but there is some significant funding for that program.

Dr. Rall explained that the AG chairs were left off of the reconstituted Committee in order to see if a richer set of recommendations might result. Dr. Green elaborated, saying that if he were an AG chair, he would try to focus recommendations to benefit his constituency. However, PSD was seeking broader viewpoints. Each AG chair was to present an update at this meeting, so their disciplines would be represented.

In making findings and recommendations, Dr. Green asked that PAC members keep trades in mind. If they sought more support for an activity, he wanted to know what funds should be shifted to it. He also wanted input on processes. PSD needs to be balanced, and to know the boundaries. He hoped the PAC would help by providing good thinking and helping with tough decisions.

Dr. Verbiscer said that the Science Committee had some outstanding questions for which they wanted PAC input. One is how to handle HR2 proposals, as noted, and the second was about the long-term plan and use of the Deep Space Network (DSN) over the next two decades. The Science Committee has also been discussing big data, though that project is wrapping up. Dr. Green said that they could get a report on big data at the next meeting. DSN is really critical, however.

Dr. Chris German asked about the respective audiences for PAC and the Science Committee. Dr. Green explained that PAC recommendations and findings will go to him and Dr. Thomas Zurbuchen, SMD Associate Administrator (AA). This is more direct than under the former subcommittee structure. Dr. Rall added that findings and recommendations will also go to the Science Committee through Dr. Verbiscer. That Committee will decide what to take to the full NAC. Dr. Green encouraged the Committee to take any aspect of the program PSD was presenting to ask questions, analyze, discuss, etc. Some presentations would have specific charges, and the agenda included discussion time so that PAC might reach some conclusions. That afternoon, they were to receive a charge from SMD R&A, for which there should be findings and/or recommendations. Another goal of the meeting was to discuss PSD's future budget, which he considered quite positive. Also on the agenda was the new lunar exploration program, for which PSD hopes to leverage past lunar exploration efforts.

The Committee on Astrobiology and Planetary Sciences (CAPS), at the National Academies of Sciences (NAS), is responsible for watching activities related to the DS. For example, Dr. Green has used their help in broadening the New Frontiers program, working on issues of appropriateness and whether the program met the DS intent. At this point, PSD is 5 years into the DS, and CAPS is doing the Congressionally mandated mid-term assessment of how well PSD is implementing the recommendations.

Dr. Justin Hagerty asked about concepts of enabling technologies to help with development of planetary spatial data infrastructure. Dr. Green said that PSD interacts well with the U.S. Geological Survey (USGS) and includes some data access of georeferenced data in Research Opportunities in Space and Earth Sciences (ROSES) calls. When PSD restructured R&A, based on a NAS recommendation, the R&A Program had not been well-aligned with the overall planetary science goals. No one wants to delete a call, but the Division needed to step back strategically and reorganize. After a couple of years, the Division sought NAS input, receiving a series of recommendations they would review at this meeting. PSD hoped for some tactical input.

In the next couple of years, PSD will begin planning for the next DS. The Earth Science Division (ESD) asked that its recent DS focus on science instead of missions, which is a new approach, and PSD will need to think about which focus is best. ESD seems happy with the results, but they now face the task of turning the science objectives into missions. There are pros and cons to that. Among other differences, ESD is leveraged with more organizations than PSD is, and has more of a commercial sector.

PSD Status Report and Q&A

Dr. Green explained that the President's Budget Request (PBR) for Fiscal Year 2019 (FY19) just went to Congress. He then showed a timeline of PSD mission events, with another list of 2017 events. In 2018, PSD will launch InSight to Mars in a window starting May 5, to land in late November. The Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-Rex) mission will arrive at the asteroid Bennu in August, and the European Space Agency (ESA) will launch its Bepi-Colombo mission to Mercury in October. NASA has an experiment on the latter mission. In early 2019, there will be a New Horizons flyby of Kuiper Belt Object (KBO) 2014MU69. A graphic of the planetary science mission suite in various stages of development included international missions on which NASA has partnered.

The PSD strategic objective is to ascertain the content, origin, and evolution of the Solar System and the potential for life elsewhere. Major activities within this charge include supporting a new lunar science and exploration program; a range of missions to numerous objects within the Solar System; enhanced efforts to detect, track, and characterize Near Earth Objects (NEOs) of all sizes under a new planetary defense program; support for international and commercial partnerships; and advancement of planetary science research and technology.

One of the major accomplishments from FY17-18 was Cassini's completion of its tour of Saturn. Meanwhile, Juno continues orbiting Jupiter. PSD selected two Discovery missions for flight: Lucy, which will explore six of Jupiter's asteroids; and Psyche, which will explore a potentially metallic asteroid named Psyche. From 12 New Frontiers proposals, PSD selected two finalists: Comet Astrobiology Exploration Sample Return (CAESAR), a probe to collect and return a sample from comet Churyumov-Gerasimenko; and Dragonfly, a helicopter-like drone to explore Saturn's largest moon, Titan. PSD has identified three landing sites for the Mars 2020 mission and will select one in the next year. Europa Clipper, to perform multiple flybys of Jupiter's ocean moon, Europa, entered the design phase.

The FY19 PBR is up about $400 million from FY17 and includes a new lunar discovery and exploration program that supports public/private partnerships and innovative approaches. There is also a new planetary defense program for NEO detection and mitigation, include development of the Double Asteroid Redirection Test (DART) to study detection approaches. The budget will support trade studies and technology development for returning Mars samples cached by Mars 2020. Europa Clipper could be launched as early as FY25, and PSD hopes to fly it on a commercial launch vehicle. Other budget areas have remained stable.

A timeline for the Lunar Exploration campaign shows initiatives addressing early science and technology, small commercial landers, mid- to large commercial landers that may be rated for humans, and a lunar orbital platform. Dr. Green described the greatly enhanced planetary defense area, which includes a new mitigation initiative. NASA will partner with the Federal Emergency Management Agency (FEMA) on this effort, and plans to look at kinetic impact techniques. Smallsats and cubesats will enable testing of deflection, and the Division is studying low-cost space-based NEO detection mission options for future competition. PSD also plans to explore options for affordable, space-based NEO search capabilities. In addition, the Discovery, New Frontiers, R&A, and technology budget lines increase in the FY19 PBR. The Outer Planets and Ocean Worlds line goes down temporarily due to the loss of Cassini, but ramps back up in FY21.

Dr. Green then provided more detail on certain points, noting that the Discovery program still has some of its early missions in operation. NASA partners with the Japanese Space Agency (JAXA), which has faced some budget challenges due to mission loss and other issues. However, NASA believes their missions will fly and continues to contribute. As noted, the Lucy Discovery mission surveys the Trojan asteroids and will be launched in 2021, while Psyche visits a large asteroid that appears to be a core remnant and will be launched in 2022. The Psyche mission will also test some Deep Space Optical Communications (DSOC) options, which will be important for the future. PSD has arranged with the Space Technology Mission Directorate (STMD) and Human Exploration and Operations Mission Directorate (HEOMD) to fly this as a technology demonstration. It will go by Mars into the asteroid belt. NASA will have a neutron- and gamma-ray spectrograph on JAXA's Martian Moons Exploration (MMX) mission, which will launch in 2024 as a sample return mission to Phobos and Deimos.

The next Discovery call will have a cost cap of $495 million, excluding the launch vehicle. Currently, there are no plans to allow Radioisotope Power Systems (RPS) in the proposals, but that is under study, and the selected mission may include Radioisotope Heater Units (RHUs). PSD hopes to release a draft Announcement of Opportunity (AO) in the fall, with the final AO next February, selections in December

of 2019, the down-selection in June of 2021, and a launch-readiness date of late 2026. The liens against the RPS involve the draw-down of the supply and some timeline issues. It is important to be good stewards of the available plutonium. PSD plans are for one mission per decade that would count against this. The Department of Energy (DOE) is not yet to the point of producing the plutonium, though it is getting ready to do so. These factors all have to be fed into the timeline. NASA does not want to have a mission sitting around and unable to fly due to a lack of plutonium.

The New Frontiers 4 AO had six investigation areas, for which it received 12 proposals and selected 2 for Phase A concept study reports. PSD will select one by July of 2019, to fly by the mid-2020s. CAESAR will return a sample from the nucleus of a comet and will address questions about how the materials of the early Solar System came together to form planets and life. Dragonfly is a rotorcraft to explore prebiotic chemistry and habitability on the ocean world, Titan. This mission requires radioisotope power, which constitutes a potential lien. In the Ocean Worlds area, Europa Clipper is in Phase B; the mission will do about 45 flybys of Europa to analyze its materials and conduct imaging. NASA is studying lander options for Europa separately. The Europa Clipper payload includes a strong suite of instruments to look at potential plume activities, analyze dust and plumes, and help determine whether Europa harbors life.

NAS has developed two DSes for planetary science, as well as a cubesat review, an R&A restructuring review, and others. The mid-term assessment is nearing completion and due within a few months. Dr. Green has asked NAS to analyze the Division's sample analysis investment strategy, as other nations are doing this and PSD wants to fit into the international framework of efforts. The next DS will cover 2023 through 2032, and PSD will send NAS the charge for this in late 2019. Dr. Green has asked CAPS if there is something to review in the interim that might also provide input for the DS.

Mission studies have been completed for the next Mars orbiter, Ice Giants system missions, the Europa lander, the Russian Venus orbiter and lander (Venera-D), and NEO search and characterization. NASA has a joint science definition team (SDT) on the Venera-D effort with Russia. CAPS has set priority areas, including missions for Venus exploration, lunar science, and Mars sample return (MSR), in addition to Mars medium-class missions, determining the next step in dwarf planet missions, re-examination of Io science, Saturn system missions, and dedicated space-based telescopes for Solar System science. PSD will select several of these.

The call for Planetary Deep Space SmallSat Studies resulted in 19 mission concepts falling into several areas. PSD will report these out at a workshop in March. The Division will look at mission architectures and potential technology development areas. The Small Innovative Missions for Planetary Exploration (SIMPLEx) effort will support a continuous call to solicit secondary payloads to fly on Evolved Expendable Launch Vehicles (EELV) Secondary Payload Adapter (ESPA) rings. This is capped at $55 million, and foreign participation will be allowed. The draft AO is out, through the Stand Alone Missions of Opportunity Notice (SALMON). Dr. Green presented a notional schedule for SIMPLEx. Dr. Dana Hurley asked about the cost range, which Dr. Green explained was based on previous experience with cubesats, in which the initial cost estimates were too low. If need be, the cost cap will change again.

Dr. Aki Roberge asked about the status of the pre-DS studies, which Dr. Green said were still in the scheduling stage. He was not sure they would be completed before the DS work begins, but the DS process will take about 2 years, and the hope is to provide input with analysis to show what is executable. Dr. Mary Voytek asked about the reports requested by Congress, which address NEO status, public/private partnerships in NEO observations and astrobiology, and the NAS studies on exoplanets and astrobiology. Dr. Green said that the intent is to offer the reports as input for two upcoming DSes; the Astrophysics Division (APD) has the next DS, and PSD's will follow. There will have to be a charge, which PSD has not sent.

The budget sets up activities in certain SMD divisions, giving detection of exoplanets to APD, while PSD covers the understanding of planets, like climate, evolution, etc. The ways in which the two divisions work together is critical in merging the science while staying within budgets. Dr. Voytek noted that the overlapping activities share members and have their own meetings. Dr. Michael New pointed out that it will be difficult for the exoplanet study group to meet the deadline.

Dr. Green said that the current DS calls for two New Frontiers missions per decade, which PSD will barely make. The next New Frontiers call should be out around 2020. Dr. Francis McCubbin asked how the study on the status of sample analysis relates to MSR. Dr. Green replied that MSR was an area of concern during the restructuring of the PSD R&A Program, but it seems to be doing fine under the new framework. PSD is moving forward with it, and there are plans for upcoming missions. Instrumentation is increasingly sophisticated, and NASA wants to ensure that its investments are the right ones.

Dr. Rall read an online question asking about the Mars helicopter for the Mars 2020 mission. Dr. Green replied that this is a budget and feasibility issue. So far, the review is going well, but there are additional processes involved. In answer to a question about how to reconcile the Mars budget with Dr. Zurbuchen's budget challenges in sample return, Dr. Green said that NASA is studying this, and it involves both international and commercial partners. Without a selected architecture to execute, funds will not be allocated. Therefore, NASA needs to determine who will execute what in order to get a budget.

Lunar Program

Dr. Sarah Noble discussed the Lunar Discovery and Exploration (LDE) Program. The White House recently amended the space policy in the direction of lunar exploration. In his presentation, Dr. Green had mentioned the Lunar Exploration Campaign, which Dr. Noble presented in more detail. The Early Science and Technology Initiative involves the following:

- Research from the Solar System Exploration Research Virtual Institute (SSERVI), ROSES18, and an archive system for sample data that is still in development and digitizing;
- Cubesats, with the Luna-H map, HEOMD cubesats, and the upcoming SALMON3 call;
- The Korean Pathfinder Lunar Orbiter Participating Scientist Program; and,
- The Lunar Reconnaissance Orbiter (LRO).

In addition, Development and Advancement of Lunar Instrumentation (DALI) is in the ROSES18 call. NASA especially wants flight hardware that can be built soon.

In the Small Commercial Lander Initiative, LDE is working on an RFP to commercial companies for hosting payloads. PSD has asked the Goddard Space Flight Center (GSFC) to build retro-reflectors, and will look for other instruments to fly. This is open to participation by other NASA divisions, as well as international organizations. The effort, some of which is led by HEOMD, seeks instruments that are ready to fly soon, while continuing to push for sample return.

There has been a lot of community input on what to do on the Moon. Dr. Noble summarized a number of the reports. The 2007 Scientific Context for Exploration of the Moon (SCEM) report had eight concepts and goals. PSD tasked the Lunar Exploration Analysis Group (LEAG) to look at what NASA has done since then. The Group found progress but not completion, listed things that needed to be done, and identified new areas like water, origins, and lunar tectonism and seismicity. NASA is now in a much stronger position in terms of landed missions. Orbital missions are less important than they once were, however.

The Next Steps on the Moon Specific Action Team (NEXT-SAT), addressed next steps and offered several findings. First, there are numerous options for lunar missions to address compelling science

questions that could change planetary science. In addition, commercial involvement should continue in the fullest practical extent, as there may be many opportunities for commercial services, with NASA as a customer. Future missions should leverage and support the LRO.

A recent workshop at Ames Research Center (ARC) addressed lunar science for landed missions; the workshop report was still in formulation. Eight lunar commerce companies participated. Dr. Zurbuchen asked SSERVI to produce a white paper on key areas of lunar science in a new era of lunar exploration, and that report should be available soon, as well. Finally, the New Views of the Moon II publication will synthesize the recent revolution in the understanding of the Moon. These efforts show that lunar exploration is in the right place now. Dr. Noble noted some of the benefits of near-term lunar missions, such as return science; advancing exploration; encouragement of industry participation; technology demonstration; and advancing planning for Mars and other destinations.

The first missions, which are still being developed, will be high-risk and depend on the capabilities of the commercial sector. Dr. Timothy Lyons asked about the strategy to design something that is sustainable in the face of political changes that shift priorities. Dr. Noble replied that one answer is to develop the commercial side, which currently has companies on the verge of being ready. At some point, they will need funding and customers, and while NASA cannot be the only source, the Agency hopes to give them a boost.

Dr. Robin Mihran Canup asked about the attitude toward scientific versus technological instruments in the private sector. Dr. Noble replied that companies want to know what NASA wants from them, so they value the science for that reason, among others. Dr. Hagerty asked if there had been any work on the interoperability of data. Dr. Noble explained that that goal is being addressed. Regarding what the commercial side can provide in terms of NASA's goals, the current plan involves noting the Agency's goals. An RFI from HEOMD sought companies that could provide these things, and most of the proposals were viable.

Dr. Roberge asked if it was clear to the community why previous lunar exploration efforts did not thrive, and what is different now. Dr. Noble said that much of the shift away from the Moon was based on political interests, rather than what NASA did or did not do. Therefore, the Agency is trying to make this work sustainable. Dr. McCubbin asked about the nature of HEOMD/SMD partnerships. Dr. Noble explained that each mission directorate leads some of the joint efforts. They have many goals in common and plan together. She was not familiar with the HEOMD budget, however. Regarding the science drivers for releasing a new set of samples, that was pending. PSD will have a call looking for consortia of interested groups. The Division wants the community to set the science priorities. Dr. Rall added that SSERVI was to release the Transformative Lunar Science white paper on its website that day. It was noted that smallsats could help with the deep space relay, another topic under discussion.

Working Lunch: Introduction of SMD AA, Dr. Thomas Zurbuchen

Dr. Zurbuchen joined PAC for a working lunch. He said he feels that the best ideas come from questions by groups like these, and he appreciates their viewpoints and experiences. Overall, the SMD budget is about $5.9 billion in the FY19 PBR, $2.2 billion of which goes to PSD. There is tremendous bipartisan support for the program. Planetary work advances the nation's science goals, and takes advantage of the commercial sector opportunities. When NASA works with the commercial side, there is recognition that that sector will be in a state of flux – some players come, some leave, and no one expects 100 percent success. This warrants a portfolio approach.

The DS presents priorities and includes science objectives, including MSR as the highest priority. Sample return is now part of the lunar exploration initiative as well. SMD is continuing to move forward while looking at how best to work with commercial, international, and internal partners. In addition to sample

return, planetary defense is a priority. The budget for that effort has tripled. Dr. Zurbuchen expects the program to operate in Principal Investigator (PI)-led, competed mode. Competition encourages prudent use of funds. DART has been started, and SMD is thinking in terms of the Congressional directive to look at NEO threats. While big, transformative missions are attractive, they only make sense as part of a balanced program that looks forward. The next cohort of the best people for tomorrow will join the effort through NASA's efforts to bring them in as PIs, co-Is, engineers, etc. Not all science questions can be answered with small technology, but those that can warrant investment. He wants a future science community that is increasingly representative of the United States as a whole, with diversity and varied opinions. It is important to deal with questions in a thoughtful fashion, in order to build excellence.

Dr. Roberge asked if there is a way to deal with the disjointed priorities sometimes found in partnerships and collaborations, as well as overlap that could be avoided. Dr. Zurbuchen said that NASA has had that discussion with ESA, and while there is no answer now, they recognize the issue. There are differing mechanisms, mismatching time scales, and other issues to address. The same situation exists with JAXA and others. NASA has annual budget issues while the Europeans are more stable, but the partnerships in Europe are varied and numerous. There is a need to find efficiency, but not every collaboration is possible, and there are some advantages to ambiguity.

Dr. Verbiscer asked about lessons learned from Cassini, which was a great international collaboration. Dr. Zurbuchen replied that it is an example of exceeding what any one county can do. Dr. Lyons asked what the vision is for the optimal relationship with the private sector in another 10 to 20 years. Dr. Zurbuchen answered that there are entities in the United States that build companies, while the SMD job is different, to build science. At the same time, SMD must consider these commercial capabilities. Launch vehicles constitute an example of an evolution. It may be that some day NASA will be able to purchase services in addition to objects. At every point, it is important to examine what is possible.

Regarding NASA's interest in life detection, the topic is not "owned" by anyone at the Agency. Life detection is at the center of many core missions. Right now, MSR is a motivator. There are also overlapping interests and missions. For example, the discovery of the TRAPPIST-7 exoplanets crosses disciplines, and two of the first papers about that system were written by Earth scientists. Life detection is a cross-cutting area of tremendous discovery potential.

In terms of the community helping NASA obtain more resources, Dr. Zurbuchen finds two things to be counterproductive. First is to pit one type of science against another, and second is to pit science against human exploration. Neither wins. There are natural connections to acknowledge and appreciate. Human exploration advances science by creating new platforms, and SMD tries to be responsive to that. The goal is to do great science, for which there needs to be demonstrated enthusiasm. There are very good stories that cross areas and agencies. He hopes everyone will focus on the rising tide. They need to do the best they can to get the best science per dollar available. There are some hard decisions, but the community can do great science.

Dr. Hurley thanked Dr. Zurbuchen for recognizing the significance of diversity, which is important in order to progress the field. Dr. Zurbuchen replied that they will see more, because it is not about words, it is about actions. There are many ways to look at diversity, including social justice. Without diversity, we limit our potential. Scientists and members of Congress have different jobs, and he feels the work with Senators and Representatives as stakeholders is going well. The best approach is to be open and clear.

PSD R&A Status

Dr. Rall presented an update on the PSD R&A Program. The Division recently released ROSES 2018. The new Cooperative Agreement Notice (CAN) for facilities is on hold pending a NAS study requested by NASA. PSD had identified which centers are best at which disciplines, and there is a need to bring the

labs and facilities up to state-of-the-art. The scope of the NAS study goes beyond the centers. The NAS study on R&A restructuring is complete, however.

The R&A Program has newly standardized templates for data management plans and table-of-work effort, so that PIs can fill in the blanks. ROSES 2017 had two pending Step-Two due dates but was otherwise almost complete. The Solar Systems Working (SSW) Program, Lunar Data Analysis Program (LDAP), and New Frontiers DAP (NFDAP) were moved to 2018. Though the overall budget did not increase, NASA Earth and Space Science Fellowships (NESSF) are now each funded at $35,000 for the stipend and another $10,000 for expenses, so that the new awards are more in line with graduate research fellowships. Applicants submitting renewals can receive the new amount. PSD has a higher selection rate than the other divisions. Dr. New explained that each division sets its own policy on how much to invest in this program, balancing NESSF with indirect funding through research grants.

Dr. Rall broke out the ROSES 2016 funding, noting that PSD funded almost all proposals deemed Excellent (E), 82 percent of those judged of Excellent/Very Good (E/VG), and 39 percent of Very Goods (VGs). Occasionally, proposals deemed Excellent are duplicative, which is why some Es are not funded. In addition, PSD will sometimes ask that lower-ranking proposals be descoped, then fund them. Among technology programs, the percentages are 82 E, 65 E/VG, and 36 VG, with smaller numbers below that. These proposals must call out missions, and some are intrinsically meritorious but have no vehicles. Overall funding speed has been affected by the Continuing Resolutions (CRs).

The Planetary Exploration Science Technology Office (PESTO) is a new Headquarters unit managed at Glenn Research Center (GRC) through a coordination office that recommends technology investment strategies, manages technology development, coordinates technologies, and promotes technology infusion. PESTO plans on holding workshops and encouraging collaboration.

Keyword analysis enables a study of investment strategies. PSD based the keywords on categories gleaned from proposals submitted from 2012 through 2016. The analysis includes all R&A awards, DAPs, Participating Scientists, and Guest Investigator (GI) programs, but not support activities and facilities. The rate of return varied from one year to another, and among portfolios, and new program officers might interpret the keywords differently from their predecessors. A chart showing investments alongside primary and secondary keywords indicated a few shifts in funding over time. Dr. Rall gave several examples, one being Outer Planets, which went down, possibly reflecting the lack of an earmark. Saturn and the Jovian systems dominate those investments. The examples show the analyses PSD can do with this system, which will help the Division determine whether it has a good programmatic balance.

<u>R&A Restructure Review</u>

Dr. Stephen Mackwell presented the Space Studies Board (SSB) ad hoc committee review of the restructured PSD R&A Program. Faced with concerns that there was a mismatch between the goals for planetary science and the core research elements, PSD pulled together a new set of elements with the goal of better alignment. A prior study of how best to revise the framework provided the guidance that was used to realign the program. However, the realignment led to some consternation in the planetary science community, along with feelings of disenfranchisement. The SSB study addressed two questions:

1. Do the PSD R&A program elements appropriately link to and encompass the range and scope of activities needed to support the strategic objectives in the 2014 NASA Science Plan?
2. Are the PSD R&A program elements appropriately structured to develop the broad base of knowledge and range of activities needed to enable new missions and maximize the scientific return from existing missions?

Committee members had to be individuals who did not have R&A funding from NASA. This presented a challenge that had a negative impact on the diversity of the group. There were three meetings in which the

ad hoc Committee sought broad community input. The Committee heard from NASA, NAS, the Planetary Science Subcommittee (PSS, predecessor to PAC) report that was behind the change, the AG chairs, and NASA science center leads.

The reorganization of the core research was first announced in ROSES 2014 and first funded using FY15 money. The Committee could only evaluate the initial funding, not the entire program. Dr. Mackwell described the strategic and focused areas, and presented a graphic representation of program consolidation, as well as a map of old to new R&A areas. There was a lot of concern about whether topics had been lost in the reorganization. The Committee sought to determine whether the implementation strategy was optimized under the new structure, how strategic funding decisions are made, and how issues of balance are dealt with under the more encompassing program elements. It is important to note that while panelists evaluate proposals, NASA program managers make the final decisions on funding.

The review resulted in a number of recommendations. The first recommendation is that PSD should recruit several external mail reviewers well in advance of the panel reviews. If panel chairs and group chiefs are recruited early, they can help identify appropriate external reviewers. Second, the Committee advised PSD to complete a process for reconsideration of proposal selection decisions, develop and implement a formal mechanism to track debriefing and reconsideration requests, and inform the community about the process. The resulting data can help provide the planetary science community have greater confidence in the selection process.

In response to PSD's first question, the Committee looked at how NASA had set up the program elements, and found that they were designed to correspond to PSD goals. In order to delve further in response to community concerns, the Committee did a keyword analysis that did not indicate that any communities had been zeroed out. More specifically, the cosmic chemistry and outer Solar System communities felt disenfranchised, but the data did not support that there had been a loss. The Committee did note that interdisciplinary science and HR2 science do not review well, and while there are some advantages under the new program, there is still work to do. The program appears to be balanced, but it needs to be watched and evaluated periodically. There is also a need for transparency.

The Committee found that the restructured program maps well to the PSD goals, but recommended development of a mechanism to ensure that HR2 proposals are not shortchanged. Another recommendation was to conduct a formal assessment of the balance at least every 5 years, possibly to correspond to the DS and mid-term review timelines. Regarding program elements structured to develop a broad base of knowledge and activities, the Committee observed that science involving surveys of planetary objects in preparation for future missions seldom fares well in review, though it was also found that the current program is optimal for science return from past and future missions. There were concerns about technology development, which should have a greater priority. There were also concerns about R&A funding meshing with mission timelines. The Committee recommended having longer lead times. The Committee advised NASA to support the development of sample return capabilities, along with appropriate containment, curation, and characterization facilities. Finally, the Committee recommended that NASA consider sustaining the critical science and technology expertise, and instrument and facilities capabilities, required for science return on future missions.

Overall, the Committee found that the reorganization works well, and yet some things need to be tweaked, and there should be diligence to ensure that balance is maintained.

PSD R&A Response to Review

Dr. Rall presented the PSD response. NASA concurs with the first recommendation. PSD practice is to request multiple external reviewers for each proposal. The subpanels are more focused despite the

restructured programs being interdisciplinary. Dr. Hurley observed that sometimes reviewers are assigned additional proposals without being invited by email. Others agreed that this happens. Dr. Justin Filiberto said that there have also been issues with some of the external review invitation emails not being sent. Dr. Noble explained that this is a problem with the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) and is being corrected.

Dr. Rall explained that the large well of proposals of similar emphasis allows PSD to have more focused subpanels, an unexpected feature of the restructuring. The external review quality varies a lot, as well. Dr. Lynn Marie Carter observed that this seems like a culture issue, as some of the reviewers do not take it as seriously as others. Dr. Stroud asked about the use of foreign or junior reviewers. Dr. Rall replied that there have been some of both. Dr. Lyons noted that the National Science Foundation (NSF) has more external reviews, which are often averaged in with the panel recommendations, though there is sometimes bias in support of their disciplines. Dr. Canup said that as a panel chief, she gets some sense of who will be detailed and who is brief. The program managers should be able to ask the panel chiefs if there were people who were not helpful. Dr. Macklin noted that if the reviews go to the reviewers late, there is less buy-in and time for response. Dr. Filiberto added that group chiefs are unable to see who has declined, which complicates adding more people later. Dr. Rall said that that could be a PAC finding. It was noted that NSPIRES has internal flags controlling who can see what. Dr. Rall explained that NSPIRES is used throughout NASA, so it is hard to make changes. Dr. Noble added that it is being rebuilt. The team has PSD input but it would help to hear from the community. Dr. Rall thought that that could be a finding. Dr. Canup said that it leads to a sense of not being respected, which in turn leads to the issue of people not wanting to do things according to procedures.

Dr. Rall said that NASA also concurs with the second recommendation, to establish a process for reconsideration of proposal selection decisions. A revision to the SMD policy on reconsideration is underway. The recommendation about HR2 proposals is another one with which PSD concurs. PSD asks panels to flag these proposals, which are then discussed internally, sometimes leading to a descope and a pilot project. PSD further concurs with the recommendation that the realignment be re-evaluated every 5 years. There is an annual review of PSD accomplishments, and the NASA science plan is typically updated every 3 to 4 years as well. Dr. Canup asked how to align funded missions with the volume of proposals. Dr. Noble said that NASA can highlight specific areas in the call.

Dr. Rall pointed out that NASA is investing in sample return and thus concurs with the recommendation to do so. He described the investments, which will be subject to a NAS study to be released later in the year. NASA also agrees that there is a need to invest in instrument and facility capabilities. The Agency wants to understand the community's lab capabilities and challenges, and has therefore asked NAS to evaluate them, identify the gaps, and advise NASA on how to be at the forefront. Dr. Verbiscer asked for details on tracking debriefing. Dr. Rall replied that it will be in the guidebook for proposers. The reconsideration rate is about 15 percent, and there have been some reversals.

The early career awards program is being revamped. PSD was giving out very few of them and wants to do something that works better. Dr. Voytek said that there were a lot of applications, and the original intent was to provide an enticement for future employers. Many applicants were selected, but few were requesting the full award amount. PSD would prefer to have a greater impact. Dr. Britney Schmidt explained that applicants had to win the award before they were given PI status at their institutions, which some places would not allow PI status for junior researchers. There are also scenarios that preclude application, which is a potential issue. Some people are not allowed to be a PI by their institutions, and this affects eligibility. In addition, moving the funds to another institution is very complicated.

Dr. Voytek explained that using the awards as help to get a position is not working. She wondered if it might be better to choose early career people who have positions. Dr. Schmidt said that the issue is the

ability of the individual to apply, which varies by institution. It might be that the award should not be related to a particular proposal but rather go to the individual. Dr. Filiberto added that, for legal reasons, most universities do not let postdocs become PIs or science PIs. Dr. Schmidt thought PAC might need a finding for further inquiry. Dr. New explained that when a PI leaves an institution, the institution can appoint a new PI, but NASA can decide whether to accept or reject the new PI. NASA considers a science PI to have all the authorities of a PI.

SMD R&A

Dr. New explained that SMD is asking all of its advisory committees to address two questions: 1. Does the SMD R&A Program have effective processes in place to solicit, review, and select HR2 projects? 2. Does the SMD R&A Program have effective processes in place to solicit, review, and select interdisciplinary and interdivisional projects? He was interested in how the process works, as well as novel ideas. He reviewed some working definitions already in existence elsewhere, including NSF. PAC was free to alter these definitions as needed. "High-risk" referred to high intellectual risk, novel hypotheses with scant precedent or preliminary data, or counter to existing scientific consensus. He compared "multidisciplinary" to fruit salad and "interdisciplinary" to a fruit smoothie, in order to make the distinction.

Dr. Stroud noted that high-risk proposals are often hypothesis-driven or rely on sparse data. The panels are likely to obsess over that. Dr. McCubbin cautioned that they might be "fishing expeditions" as well. Dr. New wanted to avoid too much of that sort of correlation. He offered to provide data or anything else PAC wanted. This is very important to SMD in trying to improve this area. All options are available. Other advisory committees discussed having separate calls and set-asides by percentage as the main variations. PSD already flags proposals as good-but-risky in a process whereby the program officers ask if there are any HR2 proposals, then select one or two in their own review. These proposals are typically descoped. Dr. Green pointed out that some reviews do not have any HR2 proposals.

Dr. Voytek explained that PSD has specific direction to identify and select some interdisciplinary proposals. It is a programmatic requirement, not an after-thought, and it sounds like it is more of a problem for other divisions. Dr. Roberge agreed. Dr. Canup remained concerned about the lack of standardization and suggested expanding the review form to include this. Dr. New said that that was an option, noting that SMD is doing a pilot project by having the definitions on the forms. Dr. Filiberto pointed out that that page is last; the definitions should be with the "notes to NASA" section. He has observed that there are people in the community who do not take the process seriously.

Dr. New said that while SMD does not yet track the HR2 pilot studies, PAC could recommend that they do so. Dr. McCubbin thought it could be useful and would like to see those data, but Dr. Rall explained that it would require a lot of staff time that does not exist. Dr. Green suggested that PAC state whether it is worth doing and why, then move on. Dr. Voytek said that PSD has used definitions with questions to help panels focus. She also noted the use of posters in the review rooms and wondered what the PAC members thought of that. Dr. Filiberto replied that posters help keep the panels on track, but high-risk proposals are an afterthought. Dr. New said that having posters is a best practice. SMD also planned to address the issue of implicit bias and was looking at a vendor for training purposes. However, research shows that too much discussion of the issue can backfire, so SMD was considering having a short video. An analysis of ROSES 2015 did not find an obvious gender bias based on first names.

NSF policy is that in cases where a grantee is being investigated in a Title IX case, NSF must be notified, and the Foundation reserves the right to terminate the grant unilaterally. This is the most far-reaching policy in the Federal government, and NASA is not opposed to following this lead. Dr. New thought that a prematurely suspended award would be reinstated if the person were to be found innocent. Universities

and nonprofits already must assure NASA that they are in compliance with Title IX. This could set up a collision of law, however, as NSF requires universities to identify the individuals.

Dr. Canup pointed out that HR2 research could fall through the cracks in two ways, first by a technique being questioned, and second by artificially high grades that might be pulled down by nonexperts. Dr. New said that SMD is always looking for proposals that fall through the cracks or are appropriate for collaboration. Dr. Green added that PSD works with the other divisions to do jointly funded programs. Dr. Lyons said that his experience has been that the HR2 questions are not necessarily novel. Identifying them is important, and knowing that they can be descoped matters.

Dr. Roberge felt that these proposals should be reviewed and funded separately, but others disagreed, expressing concern about the potential loss of expertise in the panels. Dr. German argued against holding a percentage, stating that it would be best to judge what comes in. A systematic part of the review should be identifying the HR2s. Dr. Schmidt added that sometimes, high-risk is just high-risk. Having the experience of the discussions allows PSD to reset the risk posture, which changes from panel to panel. She was not sure that this lent itself to a formula. Dr. Macklin suggested putting each proposal on a risk matrix, which Dr. Schmidt thought would help panels think about the proposals differently.

Dr. Roberge thought the HR2 proposals belonged together because of the multidisciplinary and interdisciplinary elements. Dr. New said that HR2 proposals and multidisciplinary/interdisciplinary proposals do not need to be addressed with the same process. Dr. Amanda Mainzer said that it seemed that decreasing the resources for a high-risk proposal might result in less risk. She was concerned about prioritizing high-risk proposals, since it might not work. She also wanted to know how a panel should address resource-heavy proposals. Dr. New said that if, for example, a proposed mission would consume the entirety of an incredibly rare meteorite, that would be a consideration. Otherwise, he was agnostic.

Dr. Voytek explained that the R&A reorganization was meant to address interdisciplinary work. There will always be boundaries, however, so there are caucuses in which program managers discuss the proposals on the boundaries, in order to determine the best place for them. Meritorious proposals are not left behind. Panels are told when a boundary case is assigned it to them, and they have been good about understanding that. Dr. New said that he had done a cluster analysis. The primary science programs have a lead person, as well as program scientists who work that program.

Dr. McCubbin said that some panelists are better than others at identifying and rating HR2 proposals. He would like to see these proposals flagged as such, with separate funding and the program manager making the decision. Dr. Hagerty proposed having a separate discussion in the panel, which would write up the reasons for their evaluations. Dr. Voytek observed that she was hearing that the biggest issue is the enthusiasm of the panelists, not NASA staff. PAC members agreed. Dr. Lyons advocated formalization of the process, and Dr. Stroud returned to the idea of a risk/reward matrix for all proposals in a panel. Dr. New observed that the most common grade is a VG. He asked that PAC provide him with a couple of PowerPoint slides for the summer Science Committee meeting.

Discussion

Dr. Filiberto volunteered to draft a response to Dr. New's first question, about HR2 processes. Dr. Verbiscer had some concerns about the second question, on interdisciplinary and interdivisional proposals. She and others felt that they did not yet have enough information. However, presentations on the agenda for the next day might help in that regard. Dr. Rall said that PSD is trying to lead charge in creating interdivisional programs.

Dr. Verbiscer mentioned the early career awards as another topic of discussion. Dr. New said that two of the other divisions have programs for new investigators, in the form of career awards. Dr. Schmidt agreed

to pull together some notes, though she did not think there was enough for a finding at the moment. Dr. Mainzer volunteered to draft a finding about external reviewers, NSPIRES, and appropriate changes. Dr. McCubbin offered to help. Dr. Mainzer noted that a lot of good questions were raised. She particularly wanted to address the surprise factor with NSPIRES, and suggested distinguishing the simpler items from the longer-term issues.

Dr. New explained that there is no official requirement for external reviews, but such reviews are supported as best practices. It was noted that NAS recommended renewed focus on external reviews, which help to ensure the appropriate expertise. Dr. Lyons said that good external reviewers are like gold, so the panel chair has to be diligent to identify any deficiencies in advance.

Adjourn

The meeting was adjourned for the day at 5:03 p.m.

Thursday, February 22, 2018

Agenda Updates and Announcements

Dr. Verbiscer opened the second day of the meeting by explaining that she had received an email from Ms. Elaine Denning about the March meeting of the Science Committee. Ms. Denning sought recommendations on how to address HR2 at that meeting, rather than at the summer meeting. Ms. Denning also wanted a review of findings and recommendations from the Big Data Task Force (BDTF), which PAC had not addressed at all and which was not on the agenda. BDTF had been evaluating big data at NASA for 3 years. Dr. Verbiscer thought PAC could accomplish the first task, about the HR2 process.

She next brought up the meeting schedule, noting that PAC is required to meet two to four times per year. Dr. Rall said that Dr. Zurbuchen wants the advisory committees to feed into the Science Committee and NAC schedules. Dr. Verbiscer said that the Science Committee is likely to meet in July, and PAC might meet via teleconference before then. The next face-to-face meeting should occur before the November Science Committee meeting, so September would work. Dr. Rall explained the notification requirements.

Dr. Verbiscer then explained that Dr. Green was required to appoint a vice chair to PAC. It would be his choice, but she asked if anyone was interested. The vice chair would serve in her place should she be unable to attend a meeting. Drs. Mainzer and Hagerty volunteered.

Dr. Filiberto presented his draft response to the HR2 proposal question. It stated that the process to evaluate these proposals does exist within PSD, but there is room for improvement and the process could be implemented more consistently across panels. The process should be codified in the review form. He presented six suggestions on how to do this, which had to do with voting, separate funding, a separate review, and model this based on the Early Career Faculty (ECF) or Planetary Major Equipment (PME) style, with a space for review.

In discussion, Dr. Mainzer advocated a metric for unusual use of resources, where relevant. Dr. Schmidt thought this should go into the note to NASA, and Dr. Filiberto saw it as going into a 2x2 or 3x3 matrix vote. Dr. McCubbin said that PME involves program managers and discipline scientists. That model would fit with the separate funding concept, but with the program manager deciding instead of the separate review. Dr. Roberge liked that as a solution. The reason for a separate review has to do with ranking among the HR2 proposals, which will invariably exceed the funding. The key is to have a system for ranking the HR2 proposals, and the issue is whether the program or scientists do the ranking. Dr. Filiberto clarified that he was not thinking about adding a page, but rather a box for high-risk proposals. It

would be a matrix before the panel and on the review form for external reviewers. They would ensure that the definitions were codified in order to encourage consistency, possibly on a new poster in the room. Dr. Schmidt observed that the low-reward proposals would not be considered, so she preferred a yes/no vote on whether proposals are high-risk. Dr. Canup saw a benefit from forcing the evaluation.

Mars Update

Dr. James Watzin, Director of the Mars Exploration Program (MEP), explained that the last DS laid out science goals addressing astrobiology, the processes and history of the Mars climate, and the evolution of the surface and interior. Future exploration architectures should adapt to evolving interests in Mars exploration. The MEP is investigating new, leaner Mars architectures that will find new capabilities, including those from international and commercial sources. NASA must be responsive to that global change and align accordingly.

Dr. Watzin reviewed the various Mars missions, both space-based and ground-based, as well as international. InSight is a Discovery mission, but the MEP is involved. Mars 2020 is the next major rover in development. The ExoMars rover mission will launch in 2020 instead of 2018. The Mars Science Laboratory (MSL) exploration of Gale Crater has logged over 18 km, with power from the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG); it has resulted in more than 400 published science papers. The drill feed had a major anomaly in early 2017, affecting extension and manipulation of the drill for analysis of materials. NASA determined that the situation would not improve. As an alternative, the team wants to raise the stabilizer arms and leave the drill permanently extended. This approach is being tested at the Jet Propulsion Lab (JPL), with the goal of trying it on Mars very soon.

Among other things, the Mars Reconnaissance Orbiter (MRO) mission serves as a communications relay with the rovers. MRO also surveys landing sites and conducts imaging. It appears to be quite healthy, with a good fuel supply, and NASA hopes to extend it through the 2020s. The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission is also doing well, having completed its primary mission in late 2015. It is currently in extended mission, and MEP hopes to have it available for Mars 2020. There is a plan to reduce apoapsis for improved relay performance. The Trace Gas Orbiter should reach its final orbit in the spring, then conduct primary mission science and relay operations through late 2022. The Orbiter has fuel reserves for extended mission operations. InSight will ship soon.

The next major mission is Mars 2020. Its rover looks a lot like MSL, but the instrumentation and payloads are different. Mars 2020 will do in situ measurements, ecologic exploration, and habitability and biosignatures analysis, while also preparing a returnable cache. The mission should go to system integration review soon. Dr. Watzin described parachute testing, the flight cruise stage, and other elements. For the ESA ExoMars rover, NASA is contributing an instrument called the Mars Organic Molecule Analyzer (MOMA), which will do a deep drill. ExoMars will have only a few drills, however.

The Agency is contributing a spectrograph and pneumatic sampler to JAXA's MMX mission, which should launch in 2024. The Mars Micro Orbiter (MMO) is a SIMPLEx 2014 proposal selected for risk reduction funding. After the first risk reduction study was completed, a second grant was issued for technical development. Preliminary Design Review (PDR) was to take place in March. The Mars Helicopter was in technology development to provide aerial mobility on Mars. A feasibility test determined that the aerodynamics and control are indeed possible, similar to a drone. There is extreme terrain NASA would like to access but that is beyond rover capabilities, so this technology might help. It could also do scouting for rovers.

Dr. Michael Meyer, MEP Chief Scientist, presented some mission highlights. Opportunity rover is studying Perseverance Valley, and finding some interesting things, like rock stripes running parallel to the valley. The mechanism for this lends itself to further investigation. Many results rely on a combination of

missions. Mars appears very different when there are dust storms, which pump water into the middle atmosphere. MAVEN identified this as a seasonal variation, and the mission scientists are waiting to see how much water is lost in the atmosphere in the next dust storm. Several missions, each taking different measurements, have looked at the bands of ice beneath the Mars surface, exposed in steep faces of eroding slopes. This will be useful for human exploration of Mars.

Dr. Meyer is also the project scientist for Mars Curiosity, which has traveled from Yellowknife Bay up the slopes of Mt. Sharp, finding changes in geology composition as it goes up. One of its instruments analyzes gases, helps quantify materials, and provides information on their evolution. For example, the program team was able to sort out the exposure age of some of the regolith being measured. This material was washed into Gale Crater, and the rock formation age is 4.2 billion years, though the time of the wash is yet to be determined. MEP has determined that 85 percent of the Martian atmosphere has been lost, including much of the water. An analysis of carbon from organic and inorganic sources, which is determined by examining the temperatures at which they change, indicates a fair amount of organic matter consistent with there having been a seabed.

The Mars methane background shows strong seasonal dependence. The variation is much higher than the modeling predicts, with surges. There is no good hypothesis at this point. Methane can be a product of life and indicate active processes. A HEOMD detector measures a broad range of radiation on Mars. A coronal mass ejection (CME) in September resulted in the largest solar particle event seen on the Mars surface since Curiosity's landing. The galactic cosmic ray background shows that afterwards the radiation decreases, then returns to normal levels.

MEP is currently selecting a Mars 2020 landing site from among three candidates that are very different from one another. The Jezero Crater looks like it had been a lake with rivers and minerals that interacted with water. NE Syrtis is an ancient site with a mix of minerology, diverse minerals identified from space, and possible hypothermal action. Spirit, a 2003 rover, has been to Columbia Hills, which has a hypothermal origin with possible biosignatures. Members of the science community will meet in late summer to discuss these. Dr. Meyer explained that the organics on Mars are entombed and preserved. It is not yet clear whether the features are evidence of life itself, but the science team does know that the features are associated with life. Dr. McCubbin added that on Earth, this silica is completely associated with life. If the silica on Mars is not, it would be the first instance of it not being so associated.

Dr. Watzin explained that the FY19 PBR gives PSD funds for sample return work, while also continuing ongoing Mars projects. For MSR, the first step will be Mars 2020, which will collect and cache. Another mission will fetch the samples, then load them for launch into orbit. A subsequent courier mission will rendezvous in orbit, collect the samples from the orbiting lander, and protect the samples before returning to Earth. Sample return has been a DS priority for a long time, and there are limits to what NASA can do in situ on the Mars surface.

Implementation of this goal is evolving to a lean sample return concept. A lean sample return strategy requires flexibility on requirements, and factors in cost and risk. Dr. Watzin reviewed the elements for strategic implementation. The key requirements are to land in the right place, collect samples fast, and get them back. Precision landing is a key engineering driver, in order to land close to where the samples are. This mission will be faster than current rovers. No mission has ever done a round trip from Mars, another engineering challenge. The MSR team is not looking at collecting samples on a continuous basis. They are in the beginnings of the trade space and have looked at a range of concepts in order to identify minimum requirements.

HEOMD wants to determine surface dust composition, which is included in this scenario. None of the technologies are easy. MEP hopes to use existing entry, descent, and landing (EDL) technology, though

with some tweaks to improve the landing. There is an open architecture for sample collection. The collection tubes can be dropped, set in one location, or held on the instrument, all of which will involve engineering choices on where to deposit and what to deploy. It would be ideal to have solar power, but launching the samples into orbit is a new development. NASA has been investing and has an understanding of what to do. The big challenge is that Mars is cold, and propellant could be an issue, so the team is focusing on hybrid motor technology. This requires two burns, which could be either in two stages or in one with a re-lighting. Rendezvous and capture in orbit is something NASA can do. A lot of this is engineering.

The number of tubes depends on Mars 2020, but it could be more than 30. The engineering team is examining two lander concepts. NASA is conducting technology maturation on a Mars Ascent Vehicle (MAV). The Earth return orbiter concept will involve the biocontainment as well, which requires some work. Complexity will be a factor, and biocontainment standards will be stringent. Options include sterilization via brazing and having a core within a cone. Both China and JAXA are looking at sample return in the same timeframe, the late 2020s.

Planetary Protection Officer Meet and Greet

Dr. Lisa Pratt, NASA's new Planetary Protection Officer, had previously been a member of PSS. She was new to the job, noting that the function moved from SMD to the Office of Safety and Mission Assurance (OSMA). This provides an opportunity to refocus on the facilitation of missions. The Planetary Protection Office (PPO) has deep experience with treaty and Committee on Space Research (COSPAR) negotiations. At the same time, PPO seeks to promote missions, rather than impede them. PPO has major ongoing activities with a number of missions, including InSight, which will be assessed for contamination when it arrives at the Vandenberg launch site. PPO will also work to assure cleanliness pre-launch and will examine the processes involved in launch and faring. This mission will have cubesats outside the fairing; these will need to be assessed nonetheless. Cubesats are a new challenge, as they are broadly manufactured. NASA is working with the manufacturers to help them understand what is needed.

PPO is working with the Mars 2020 team in a number of areas, including the tubes that will be involved in collection. One of the issues is balancing the air in the tubes. PPO is also monitoring how the mission team will ensure the safety of the cache. Another consideration is cubesats that could go with Mars 2020, stowed away from the faring. A new microbiology lab at JPL will help NASA update the techniques used to monitor clean rooms, etc. PPO is also working with the Europa Clipper mission on its planetary protection requirements, including decisions regarding a potential lander. PPO is closely working on the MOMA instrument going to ESA, as there has been concern about a shutoff.

PPO will communicate more and more with the human exploration community, especially as crewed missions to Mars approach. Humans will automatically change the planet on arrival, and there are international conversations on this. Dr. Pratt would prefer that humans not start out in special regions. PPO wants to work with HEOMD on collaborating with the commercial sector, which is ahead of NASA in developing sterilization methods. Her team is also looking at sample return facility requirements. There have been conversations about the lunar gateway, including the lunar polar regions and the organics.

It is important that the commercial side understand and share NASA's planetary protection concerns, and Dr. Pratt would like to develop some shared protocols. There should be high standards, but NASA needs to identify standards that can actually be met. The regulatory relationship with the Federal Aviation Administration (FAA) and Department of Commerce is evolving.

Joint Workshop on Induced Special Regions

Dr. Meyer explained that this workshop was prompted by PPO and MEP concerns about hydrated minerals becoming an issue if a special region were to be affected by the crash of a radioisotope-

generated lander or even the impact of a rover, causing deliquescence. This had been an ongoing and unresolved conversation, which led to the idea of having a discussion among experts. Dr. Meyer noted that his charts did not reflect NASA or PPO policy. Conveners included Dr. Meyer, Dr. Catherine Conley (NASA's previous Planetary Protection Officer), and Drs. Robert Lindberg and Clive Neal. The workshop definition of "special region" was a place where water activity and temperature are high and persistent, and long enough to plausibly harbor life.

The workshop participants were very knowledgeable, but pre-workshop questions made it clear that the two sides were not really that familiar with each other. That led the conveners to send out a set of questions about capabilities of Earth organisms, natural conditions on Mars, and the possibilities of the Mars environment being altered. This, in turn, resulted in 26 pages of anonymous answers. Many participants answered only one question. While no names were involved, the conveners did color-code the respondents to track their comments. Analysis indicated what they did and did not know, while identifying the strengths and gaps.

The workshop, which took place in late 2017, began with a review of goals, definition of terms, and discussion of answers to the questions. Then the workshop introduced three new, more specific questions and provided additional information via presentations. The new questions sought to determine what a safe stand-off distance might be, or a formula to derive a safe distance to a purported special region. There were also questions about Radioisotope Thermoelectric Generators (RTGs), other heat sources, and their ability to induce special regions. The final question asked if it is possible to have an infected region on Mars that does not affect the rest of Mars. Participants broke into groups, addressed each question separately, presented their conclusions, and then remixed into new groups to synthesize answers.

There were some areas of general consensus. First, there is a formula for safe standoff distance that would decrease with time. The longer a spacecraft is on the surface, the less contaminated it is. However, an analysis should ensure that risk is minimized. Second, an RTG on Mars would not create a special region, but the result depends on the kinetics of melting, freezing, deliquescence, and desiccation. A buried RTG could induce a special region but would not pose a long-term contamination threat to Mars, with the possible exception of a migrating RTG in an icy deposit. Induced special regions can allow microbial replication to occur, but that is unlikely to globally contaminate Mars. An induced special region would be isolated, and microbial transport elsewhere is unlikely.

Areas for additional research include kinetics, which determines the intermediate state in transition and should be studied. There is a need for models to understand the details of atmospheric processes for surface transport rates. There is also a need for data on Earth organism propagation via airborne dispersal and survival. In addition, data are needed to understand small-scale features within the first 5 meters of the subsurface, and if there are deep groundwater systems.

The workshop did not discuss metabolisms. On Mars, water activity and temperature are the huge limits, and investigators need that information before moving on. There were several microbiologists at the workshop, which started with what is known rather than possibilities. There is a huge debate on how long the microbes would need to divide at the right temperature. The workshop report is still being drafted, and it will have more on this. The three questions occupied the entire 3-day workshop. Dr. Schmidt said that this sounds like a good way to start the discussion, but other discussions will need to follow. Regarding an induced transient phase, modelers indicated that it would happen quickly, from hours to days. There will be more in the paper.

Planetary Data System

Dr. Thomas Morgan explained that the Planetary Data System (PDS) has existed since 1989, to address data returned by science missions. PDS uses discipline-oriented nodes and support nodes, with a small

project office at GSFC to coordinate activities. PDS works with every NASA planetary mission in order to obtain a complete mission archive, and strives to maximize the usefulness of the archive, which has become a basic resource for scientists around the world. The effort relies on stable standards.

The current archiving system, PDS4, is based on a well-defined planetary science information model and is extensible for the future. It has become the international standard used by ESA and others. Dr. Morgan showed the nodes, subnodes, and data nodes, with the associated topic areas and science nodes leads, who are the heart of the system. There are also support nodes for engineering and the navigation and ancillary information facility. PDS is on the small end of big data. A graphic showed active mission data status as mostly green, with yellows usually involving a single instrument.

Dr. Maria Banks described the roadmap study chartered in 2015 in order to chart the future course for PDS. The report was released in mid-2017. The 16-person study team discussed a range of topics. Among the 19 findings were 10 findings of fact requiring no action, 2 requiring program-level action, 5 that PDS could address on directly, and 2 involving both program- and project-level actions. PDS identified the highest-priority findings to address first. PDS was directed to develop a plan to allocate a 10 percent augmentation over the next 2 years to address high-priority roadmap issues, including four to be addressed immediately. These include completion of a project plan, increased staffing of the project office, training for archiving focused on small providers, and accelerating the PDS3-PDS4 translation. The office also brought on a training and communications coordinator on a temporary basis; this may become permanent. In addition, PDS held two workshops, conducted one-on-one training, and sought additional cross-node support. The team is in the process of developing flexible training modules, and is planning booths at science conferences.

The upgrade from PDS3 to PDS4 was already in motion and has obtained new funds for translating the data. There are plans to translate data from missions that recently ended. Dr. Banks described the next priority data sets to be addressed, as well as specific missions going through translation plans. There is also an effort involving the instrument teams. For the next 2 or so years, PDS will focus on website redesign, tool development and cross-node coordination, PDS 3 to 4 translation, bringing on the training coordinator, external customer satisfaction measures, and cybersecurity.

Dr. Hagerty noted that the roadmap discussed some things that PDS does not do, and along with this, there are some erroneous expectations in the community. Dr. Morgan agreed, adding that PDS has four standard formats, and some users want or expect something else. This is an archive, and there are other players. If they are to make the data more user-friendly, they will need more funds. However, this is beyond his area, and the community and NASA need to have the conversation in order to control expectations. Some of the issues are bigger than PDS.

Deep Space Network

Dr. Joseph Lazio explained that there are many people involved in data delivery via DSN. The Network has three complexes spread among Canberra, Australia; Goldstone, California; and Madrid, Spain. A graphic showed current missions enabled by DSN, including many from SMD and many international missions. NASA requires that telemetry, tracking, and command reach 95 percent accuracy, but over the past 5 years, the actual rate has usually been 99 percent. Science highlights include comet images from MAVEN, Pluto data from New Horizons, Jupiter information from Juno, and Saturn information from Cassini. DSN is enabling three new Mars missions, and asset demand will be manageable despite initial concern about the 2020-21 Mars contention period, which resolved itself. National planetary radar assets include Goldstone; Arecibo, Puerto Rico; and Green Bank, West Virginia. At the moment, the Canberra radar is being evaluated. Dr. Lazio described the Goldstone Solar System radar, the 2012 TC4 observation, and the facility's cumulative history. Arecibo experienced outages due to a combination of planned maintenance and Hurricane Maria.

The current suite of antennae is being augmented through 2025. Each site will have four 34-meter antennae and one 70-meter antenna; Dr. Lazio would like additional 34-meter antennae. The history of downlink performance from 1960 to the present shows a surge in 1980, with an increasing trend since then. In order to keep the upward trend, DSN is looking at a range of technologies, including solid state power amplifiers, smallsats, next-gen clocks, and software-defined radios. New digital backends are already happening, and spacecraft are now built to send data back with little or no bottleneck. On the other hand, there is so much going on at Mars that the missions interfere with each other. Moving up in frequency could help that. The Psyche mission will carry an optical communications demonstration terminal that should relieve spectrum congestion. Dr. Lazio described some of the flight and ground technologies, along with technology development projects. Mars images are relayed to MRO or another relay orbiter, then to Earth. In the future, this may be optical. An icy moon mission will require a relay as well, but the technology exists, so this will be relatively easy.

Dr. Hurley asked about plans to work with the commercial sector. Dr. Lazio replied that SpaceX and other firms have shown interest in using DSN, though NASA has contracting protocols. He was not aware of a commercial entity discussing development of its own DSN-equivalent. To go to Mars, a mission will need relays and antennae, which is not being done outside of NASA. Regarding whether DSN could become a limiting factor, it remains in NASA's near-term plans, and the commercial sector has not inquired at any level of detail. Dr. Meyer added that for optical communications, an issue is cloud cover. Dr. Lazio explained that the frequency of cloud cover would only warrant five or six locations, and NASA does not need to build all of these; ESA is building some. Smaller apertures would only work with something close, like the moon, but not Mars. Multiple human missions and lengthy missions would affect demand.

NAI and NExSS

Dr. Voytek discussed the NASA Astrobiology Institute (NAI), which is PSD's first virtual institute for science. NAI is 20 years old, with a mission statement to provide leadership for NASA space missions, IT for research, collaborative and interdisciplinary research, training for the next generation of astrobiologists, and education and outreach, all in order to help discover life. The model has brought in many energetic early career members who are pushing the field forward and sharing ideas. NAI is part of NASA's Astrobiology Program. It has geographically distributed nodes, which Dr. Voytek described. Once a budget is approved, the Astrobiology Program will move forward with Cycle 8 selections.

CAN 6 includes a lab at the University of Washington that will use the results of modeling to distinguish between habitable and uninhabitable worlds. The node at the University of Illinois identifies the shared physical principles underlying the emergence of features of life. The University of Wisconsin is looking at signatures of life on terrestrial planets, while the University of Southern California is studying life underground, as the subsurface could hold as much as 80 percent of a planet's life. This could affect life detection on planets that are not as strongly affected by their suns as Earth is. MIT is looking at foundations of complex life and how to use them to detect life.

The CAN 7 projects include the SETI Institute's look at changing planetary environments and the fingerprints of life. JPL is focused on astrobiology at the rock-water interface of icy worlds. A GSFC node studies the origin and evolution of organics and water in planetary systems. ARC is examining the evolution of prebiotic chemical complexity and the organic inventory of protoplanetary disks and primordial planets. The node at the University of California (UC) Riverside addresses alternative Earths and persistent inhabitation on a dynamic early Earth. The University of Montana and Georgia Tech are collaborating on identifying the forces that bring about major transitions in the evolution of biocomplexity. Finally, the University of Colorado node explores the mechanisms of rock-powered life.

International partners host students and link to these activities. Other NAI efforts include some early career funding, workshop support, symposia, and more. The Institute funds the Library of Congress (LOC) Blumberg Astrobiology Chair, which supports an investigator for a year to use the LOC, also sponsoring two public events. NAI met its goals of encouraging this type of science and developing a community of interested scientists. However, there has been less success in getting involved in missions, and the Institute is examining how to do this. Dr. Green has asked them to do an exercise to explain measurable life indicia on a "ladder of life detection." This has been circulated and adopted, with the purpose of stimulating discussion.

Dr. Lyons stated that when gases are identified as potential biosignatures, the discovery will come from NAI and the astrobiology community. The question was how to shift that over to astrophysics and exoplanets. He also highlighted the importance of spectroscopy in the near-ultraviolet (NUV) to access key molecules. Dr. Roberge said that she is the study scientist for APD's Large UV/Optical/IR Surveyor (LUVOIR) mission concept, which has included a NUV channel for exoplanet spectroscopy. She also belongs to the Nexus for Exoplanet System Science (NExSS). Dr. Voytek noted that APD's LUVOIR and Habitable Exoplanet Imaging (HabEx) study teams include many NExSS members. The exoplanet community is very involved, and they apply a lot of their information to the biosignature effort.

NExSS is a cross-division initiative to coordinate research. It does not fund new research, but rather enables sharing and synthesis that is generally not supported. The overarching goal is to further joint strategic objectives to explore exoplanets in terms of habitability outside the Solar System. Exoplanet research cuts across SMD divisions, and NExSS will leverage existing SMD programs to advance exoplanet research in biosignatures, habitat detection, and planet characterization. A coordinating network is virtual, providing opportunities to share information and ideas, while also fostering new collaborations. It provides innovative ideas for implementing novel networking strategies, supports development of community standards, and supports means by which investigators can plan and conduct research. Dr. Voytek presented a graphic depiction of what each SMD division can contribute. PSD has an exoplanet research program in addition to the Astrobiology Program. Another graphic aligned the teams by interest area. This is very multidisciplinary, with diverse methodological approaches. NExSS has also selected two postdocs to cross-pollinate between teams, usually astrobiology and astrophysics.

Dr. Voytek listed five measures of success: addressing interdisciplinary research through new collaborations; ideas for new and innovative missions; identification of the new, targeted technologies necessary; contributions to DS panels; and enhanced international engagement. Dr. Roberge observed that this seems to be going well, but it was not clear what work should be done that is not occurring. Dr. Voytek replied that there is a sense that astrobiology is not being incorporated into missions. Sometimes geology is done in the place of astrobiology, for example. The astrobiology community is seldom involved in the early stages of mission development, instead being called on for activities like the selection of landing sites, which is late in the process. They should be involved sooner. The technology is being coordinated by PESTO now.

SSERVI

Dr. Noble discussed SSERVI, which began as an extension of the NASA Lunar Science Institute and now includes other destinations for human exploration. The focus is on integrating science and exploration. Like NAI, it is a virtual institute, with its central node at ARC. Collaborative teams include individuals who would not otherwise cross paths professionally. Long-duration funding of the teams enables results and research continuity. SSERVI advances science, conducts cross-disciplinary research, and supports ways in which to do research. Like NAI, the outreach component is being transitioned elsewhere.

There are seven focus areas, which Dr. Noble listed. The SSERVI teams published 112 journal articles in 2016. A color-coded graphic cross-listed the teams with focus areas on a continuum between science and

exploration. Most work is done in the areas of greatest conjunction. The PIs and co-Is are geographically distributed across the United States, and there are international affiliates and associates, as well. A number of shared facilities are open to the community. The Solar System Treks Portals (SSTPs) are free, web-based applications that enable high-quality, detailed visualizations of planetary bodies using real data from NASA exploration. SSTPs are quite functional.

An annual summer Exploration Science Forum (ESF) brings the teams together but is open to the community as well. All past forum recordings are available online. SSERVI members and leadership participate in many workshops, write papers, and are active in AGs. SSERVI also brings together focus groups to share science and exploration strategies with the community. Shared postdocs facilitate collaboration between teams. The next CAN draft will elucidate the extent to which SSERVI may focus on lunar exploration.

Ceres Definition Team

Dr. Michael Kelley, who has a background in small bodies and led the Dawn effort, explained that Ceres is the largest asteroid in the Solar System's main belt. He leads the pre-decadal SDT for Ceres. The original goal was to finish work by the end of FY18, but the group has been slow to start, and so the resulting white paper will be released later. That white paper will discuss future science goals for Ceres, mission designs, and cost estimates. JPL, the center lead, and had a call for applications late in 2017, receiving 39 on time and 2 late. These are encouragingly broad. The issue was in getting the team appointed, and there is concern about the center teams needing to do Discovery work at the same time.

Dr. Rall explained that the members must be Special Government Employees (SGEs), as part of the NASA committee restructuring. They require the same level of openness as an advisory committee. The requirement comes from outside of NASA. There are also issues about how much time an SGE can give. Dr. Kelley added that the process is complicated when it involves foreign nationals, and two applied for this. There is a category for them, but he was not sure how that will go. There are back-up selections if needed. Dr. Green wanted the missions to be open-ended, but the focus seems to be on New Frontiers. However, Dr. Kelley does not want to box in the SDT.

Planetary Defense Coordination Office

Dr. Lindley Johnson, Planetary Defense Officer, discussed the activities of the Planetary Defense Coordination Office (PDCO). This office oversees the detection of NEOs that might impact the planet, while also overseeing the range of potential effects and developing strategies on how to deal with such an event. Dr. Johnson showed the various elements involved in the Observe, Orient, Decide, Act, Assess (OODAA) loop, developed by the Department of Defense (DOD). NASA uses other wording to characterize its process: detect, follow-up, characterize, plan, coordinate, mitigate, assess. The process could involve in-space deflection of threats, which would require international cooperation and possible campaigns by multiple space agencies. The asteroid redirect test would fall into this effort. All of the projects fit somewhere on this loop of activities.

Dr. Kelly Fast, NEO Observations (NEOO) Program Manager, described the current survey systems in NASA's NEO search program. These include LINEAR/SST, the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE), the Catalina Sky Survey telescope, the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), and the Asteroid Terrestrial-impact Last Alert System (ATLAS). The Minor Planet Center of the International Astronomical Union (IAU) is the worldwide clearinghouse, operating as a subnode under the PDS small bodies node in a contract with Harvard. The Center for NEO Studies at JPL does high-precision orbit modeling to determine if an object might pose an impact threat. Additional observations help to decrease or retire the risk.

Dr. Fast then presented the data for various sizes of NEOs, comparing what has been discovered against what is presumed to exist. For 1 km and larger objects, most of the discoveries were made in the early 2000s. However, more of the 140-meter and larger Near Earth Asteroids (NEAs) have been discovered in recent years, primarily by Pan-STARRS and Catalina. In 2017, there were 2,057 discoveries alone. The Potentially Hazardous Asteroids (PHAs) come within a certain distance of Earth and are followed carefully. There are more than 1,800 such objects, along with 107 near-Earth comets. Dr. Fast presented additional comparison data by size over time. The predicted number of not-found objects has decreased significantly, but these objects still constitute about two thirds of the total.

In addition to finding and characterizing NEOs, NEOO relies on the NASA Infrared Telescope Facility (IRTF), radar (Goldstone and Arecibo), and the Spitzer. The large NEA Florence has been observed to have two moons. A planetary defense campaign used the asteroid 2012 TC4 in an exercise that included international participation. The exercise found the asteroid, characterized it, and did modeling and communications. It was determined that 2012 TC4 will not be a significant threat. During NEOO operations, Pan-STARRS accidentally discovered ‘Oumuamua, an elongated body identified as the first interstellar object.

Dr. Johnson listed the asteroids that passed between Earth and the moon in 2017, at a rate of about 1 per week. Four came within geosynchronous orbit, and 2012 TC4 was the only one of these identified years in advance. Though most were quite small, several were sizable, at 30 to 70 meters. There has been one in that size range in 2018 thus far. PDCO works with the international community in formalized agreements through the UN Committee on Peaceful Uses of Outer Space (COPUOS). There is an International Asteroid Warning Network (IAWN) and a Space Missions Planning Advisory Group (SMPAG) as well. It is through these groups that NASA would inform other nations of findings that might affect them.

Through the Worldwide Observing Network (WON), there were about 22 million observations from 47 countries in 2017. Agreements are in place regarding thresholds for alerts and actions. Deflection in space would likely occur only with objects 50 meters and larger, with a probability of striking them. PDCO works with FEMA via the Planetary Impact Emergency Response Working Group (PIERWG). Dr. Johnson listed the Group’s goals and objectives. Another concerned organization is the Detecting and Mitigating the Impacts of Earthbound Near-Earth Objects (DAMIEN) Interagency Working Group (IWG), which has representation from across the government.

Next, Dr. Johnson presented the planetary defense timeline, reflecting a strategy devised in 2016. PDCO is working on the NEO preparedness action plan to identify specific actions for agencies and departments throughout the U.S. government. A NEO SDT looked at detection and characterization capabilities. A major finding is that it is known that there is a large population of objects, and a space-based instrument will be necessary to meet the requirements set out by Congress. Finally, Dr. Johnson reviewed the PDCO flight mission projects, which include NEOWISE continuation; the Near-Earth Object Camera (NEOCam), which is in extended Phase A; and DART, which is in Phase B.

Dr. Mainzer asked about the completeness of identification at the various levels. Dr. Johnson replied that 95 percent of the larger objects have been observed, but only about one third of the 140-meter objects. Smaller objects that could cause damage are at about 1 to 2 percent. An ARC project is studying the effects of impacts regarding size and composition. Dr. Schmidt asked if there is a need for more than a space-based resource. Dr. Johnson explained that the SDT report found that a single space-based asset would be sufficient to carry out 15 to 20 years of operations, but it would help if NASA could augment that with a ground-based telescope. A good infrared capability would help, as well.

Findings and Recommendations Discussions

Dr. Filiberto presented an updated slide incorporating comments from the earlier HR discussion, and Dr. Mainzer had a draft on NSPIRES. Dr. Filiberto had altered some wording and changed some of the suggestions regarding the review form for both panel reviewers and externals, whether to add a yes/no vote on HR2, and having text box to describe why a proposal is high-risk. For panels, there were suggestions to discuss whether a proposal is high-risk as a separate category, and to vote on high-risk status. Finally, there was the suggestion to have dedicated funds for high-risk proposals.

Dr. Schmidt advised having reviewers describe risk for proposals deemed high-risk. Dr. Filiberto explained that he removed the matrix suggestion because the proposals need to be inherently high-impact for the discussion to matter. Dr. Roberge thought they should still force the issue, but Dr. Hurley was concerned about adding work. Dr. Filiberto shared that concern, noting that the discussion could be long. There was discussion about ways in which to keep the process simple. Dr. Lyons though they should just identify proposals that might provide special opportunities. This would be a special item on a review sheet. He felt that if identification is not a separate process, it will not be brought up. Dr. Filiberto changed the suggestion to voting yes or no on HR2 as a panel. He also added to the suggestion that there should be text stating that this is a good thing and providing definitions.

Dr. McCubbin asked about scores that are low due to the risk. Dr. Stroud suggested having panels mention how to descope, or at least say where the risk is. Descoping could result in pilot studies. There was concern that this would result in the rewriting of the proposals. Dr. Canup gave an example of a NASA mission that began as a proposal deemed risky, with a successful pilot project after the program officer chose to give the PI one year to prove feasibility. Dr. Filiberto thought this could lead to similar situations, though it would help mid-level proposals rise rather than low-level proposals. Dr. McCubbin maintained that having the risk impact matrix would help the program manager see where to review the overall score elements. Dr. Schmidt thought it would be helpful to tell proposers why they got the score. Dr. Filiberto cautioned that panels are not supposed to rank proposals. Program officers already deal with these situations. Dr. Canup observed that the more people involved in the decision, the more it evens out.

Dr. German asked for discussion on the right amount for the separate pool of funds. He felt that PAC was there to advise PSD, and that this was appropriate. Dr. Mainzer thought that not all R&A programs will be amenable to HR2 proposals. She did think they might recommend that NASA emphasize HR2, however. At the same time, she did not want to be overly prescriptive. Dr. Rall said that he would be comfortable with something like “not more than 15 percent of the budget for this should go to HR2.” Dr. Schmidt shared Dr. Mainzer’s misgivings about being overly prescriptive. She suggested that there be a statement that NASA has interest in disruptive technologies or proposals that have difficulty being assessed in review panels. Dr. Filiberto liked Dr. Rall’s “not more than” construct, adding that the funds do not have to come from a separate pool.

Dr. Rall said that funding is fungible, and even a separate pot is not fenced off. Some programs will be inherently non-risky. Dr. Filiberto explained that he wanted the panel to have the discussions. Dr. Rall confirmed that at present, there are usually one or two HR2 proposals selected. The program sizes vary. Also, PSD no longer does 1-year pilots because they are not long enough. Pilot programs last for 2 years now. Dr. Stroud thought that this information should go to the community so they know they can submit these proposals, and Dr. Canup wanted to see the language in the AO. Dr. Green pointed out that SMD will want to have a uniform approach, with boilerplate language in ROSES. Dr. Filiberto said that he would send a revision of his slides to the PAC members.

Dr. Mainzer presented her draft findings on NSPIRES, which began with a preamble on external reviews and the need for adequate time to write reviews. She next made four points:

1. There is often a delay between the time the external reviewer is identified and when he/she receives a review.

2. The current system does not always notify reviewers about additional proposals assigned to them, leading to surprises at the last minute.
3. Sometimes, external reviews are not universally viewable to panel members.
4. The amount of information the group chief can access is not consistent across all R&A programs.

Some of these are software issues that IT does not address well, or there may be a need to change the default settings.

Dr. Hurley said that if, as a group chief, she assigns a proposal to a reviewer who declines, she does not get an email telling her this. Dr. Schmidt suggested adding to the second point that reviewers do not have the option to decline proposals. If they do not know the proposals exist because they were added later, for example, the reviewers cannot decline in time for the panel chief to assign them to someone else. Dr. Filiberto said that it is important to know if reviewers have logged in, which Dr. Hagerty said is a factor in quality. It was agreed that NSPIRES does not provide necessary information in a timely manner.

Dr. Mainzer next read three recommendations. First, to ensure that reviewers always have the maximum time to complete their assignments, NPSPIRES should be modified to provide automated notifications when a new review is assigned. Second, NSPIRES should be modified so all panelist can see all external reviews. Finally, NSPIRES should be modified so that group chiefs can always see all reviews for the panel. Dr. Mainzer noted that the second recommendation addressed the default setting to enable panelists to see all external reviews, which she made more specific. The default should be visibility. Dr. Canup suggested allowing the group chief to see instantaneous status of all reviews, including those that have been declined. She advised adding a statement on the need for a quick response, with no delays greater than 48 hours between the person being contacted and their acceptance or decline. Group chiefs need situational awareness. Dr. Rall said that he would ask if it can be put into the revised NSPIRES.

It was noted that program managers do not want reviewers to reveal that they are to be panelists. Dr. Hagerty asked about the NASA Research Education Support Service (NRESS), which Dr. Rall said had some issues due to staff turnover, constant updates, and issues with a training module that was not released. The primary problem is that they do not have sufficient staff. There is increasing proposal pressure across all divisions, but the contract was sized to something smaller, creating a mismatch. Dr. Mainzer said that she would send a revised draft to the PAC members.

When Dr. Green returned, Dr. Verbiscer told him that some committee members were concerned that Ceres SDT members must be SGEs. Dr. Rall explained that the time limits are 60 continuous days, and 130 over course of a year. Some individuals, such as AG chairs, are not SGEs because of limitations on what they can do. Dr. Green said that the Ceres SDT will be PSD's first SDT to have the members be SGEs; the Division will report back to PAC. These SDTs are leading up to the DS, at which point they will disband. However, there are other SDTs with a higher level of visibility. They are important and PSD uses them flexibly. Dr. Roberge was concerned, noting that SDTs do not set requirements for the DS. She did not think that volunteers who are not setting requirements should be counted as SGEs.

Dr. Green explained that there is a lot of input that will go to the DS. This is the current environment, and PSD is trying to follow the process. The Division will see if there is a basis for advocating changes in the system afterwards. He noted that APD is leading the charge on bringing on SGEs with green cards. Meanwhile, PSD is executing, with plans to determine lessons learned and see where that goes. The Division needs the input from doing an SDT with SGEs in order to have credibility. Dr. Rall added that the AGs have been disentangled from the advisory committee process for PSD. Dr. Green said that PSD tried to integrate the chairs into PSS, and now wants PAC to wear a broader hat. The AG chairs were

representing their communities, but planetary science has a lot of issues and PSD wants opinions not drawn from a constituency.

Regarding the selection of multidisciplinary and interdisciplinary projects, while more information was coming to PAC, it was noted that they had only discussed the virtual institutes. Dr. Green said that this area is an order of magnitude better than it was 5 years ago. Further concern was expressed about proposals that fall into the grey area of formation versus evolution. Dr. Stroud maintained that some of the proposals under Origins of the Solar System fell through the cracks. Dr. Green said that if PAC wrote a recommendation on this topic, PSD could examine it. Dr. Rall said that another area that might lend itself to a recommendation was the division between Emerging Worlds and SSW. Dr. Stroud suggested that PAC itemize areas that dropped off. The interdivisional support for Emerging Worlds disappeared; there is not a place for it in APD. Dr. Green said that PAC would recommend asking APD to join PSD on that. SSERVI is inter-directorate and interdivisional, with APD involvement. Dr. Carter said that she had heard concern about field research and mapping not falling into an obvious place.

Ms. Doris Daou read a message from Dr. Melissa Morris stating that Emerging Worlds will allow proposals that address planet formation in general and that are relevant to exoplanets. Proposers must show relevance to the Solar System. Dr. Green said that he would love to see more divisions participate in more PSD efforts. There was a successful comparative climatology series for which he would like to have a new call, with all of the divisions contributing. Dr. Hagerty explained that mapping has been discussed within the mapping community, but the placement of the terrestrial analog work is unclear. It was noted that it must be related to instruments, and the review panels might have had confusion.

It was generally agreed that PSD has effective processes for interdisciplinary and interdivisional projects. Dr. Schmidt said that NAI infusion into missions becomes problematic because missions are instrument-oriented. People from the astrobiology community need to be involved in the panels and mission proposals. The concepts for life detection are not common to planetary reviewers, so there are differences in how they think about mission design. This is something that requires effort. Dr. McCubbin added that the instruments for life detection are not matured to the required Technology Readiness Levels (TRLs), which is one reason for the focus on sample return. Dr. Schmidt asked if the concerned investigators are getting onto the mission teams. Part of the issue is that while NASA might be moving to evaluating life detection technologies, the concerned scientists are not on the right teams to select instruments or missions.

Adjourn

The meeting was adjourned for the day at 5:16 p.m.

Friday, February 23, 2018

Agenda Updates and Announcements

Dr. Verbiscer suggested that PAC review draft findings. They returned to the question of whether SMD has the proper process in place to solicit, review, and select HR2 proposals. The overall PAC answer was that PSD does, but it can be better, with more consistent implementation. The current process, to fill out the back page of the review and discuss it during the debriefing, is not always implemented seriously or even done by the panels. All PAC members agreed on this.

Next, PAC discussed the associated draft suggestions. These stated that the process needs to be implemented more evenly and codified, with definitions, in the review. The ROSES announcement needs to be adjusted to encourage HR2 proposals as well. Implementation might be done by adding text to the

review form for both panelists and external reviewers stating that HR2 is a good thing; adding a yes/no vote on HR2; or adding a text box describing why a proposal checked yes is HR2. Options for panel activities included discussing whether a proposal is HR2 as a separate category, having a yes/no vote as a panel, and/or filling out a text box describing why. Program officers might have a separate fund for HR2 proposals as well.

It was decided not to include a percentage in the statement for the separate fund. Dr. Rall suggested adding "at the discretion of the program caucus and selection official." He noted that they needed to avoid giving the impression that there are additional funds for these proposals. If it is important, the program officer will select it. Dr. Green advised saying something positive, like funds for HR2 proposals should be separate and protected. Dr. Schmidt observed that the reviewers need to select the best proposals, and this codifies disruptive proposals. The program should have multiple ways to look at value.

It was also agreed that measurement and assessment would be helpful. Dr. Rall said that PSD will keep track, as the Division does a lot of tracking. The statement was briefly changed to ask NASA to track and report. However, it was noted by multiple members that there are no metrics on the results or relative strength of typical grants, so the "report" element was dropped. Dr. Green said that every year, PSD puts together a series of milestones through the R&A Program, which will involve PAC. They can identify some of the HR2 work at that time. Dr. Rall added that they were making recommendations for SMD-wide standards, so what they advised could end up as something different. The suggestions were changed to recommend that NASA track HR2 proposals within existing reporting procedures.

Dr. Verbiscer reviewed the second question, about interdivisional and interdisciplinary projects. The draft PAC answer was that yes, NAI, NExSS, and others solicit, review, and select such projects. Dr. Hurley suggested adding that the results of these efforts are being infused into technology and instrument development and design. Dr. Schmidt wanted to note that NAI has some influence on the thinking about planets and missions, but more could be done to ensure that the astrobiology viewpoint is included. Dr. Stroud agreed, noting that there is still room for improvement in some areas.

CAPTEM

Dr. Kevin McKeegan provided an update on the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM). The name encompasses what this group addresses; it is for the science community involved in extraterrestrial materials. CAPTEM operates as a standing review panel charged with evaluating proposals requesting allocation of such samples from NASA collections. This requires a number of subcommittees, including ad hoc or standing subcommittees to address certain issues. Dr. McKeegan listed and described the subcommittees.

CAPTEM meets at least twice each year, with one face-to-face meeting. Recent activities include updating the charter, providing input for long-term planning and the mid-decadal review, and initiating a review of stardust curation and allocation. The Team also consulted on Johnson Space Center (JSC) Astromaterials Research and Exploration Science (ARES) preparations for asteroid samples from upcoming missions. There were initial discussions of advanced curation initiatives, and there have been ongoing discussions of informatics.

Dr. McKeegan next reviewed curation, analysis, and planning activities by mission. For JAXA's Hyabusa-2, to launch in 2020, NASA will receive 10 percent of the samples from the NEA Ryugu. CAPTEM will soon visit the JAXA curation facility in order to begin work. For OSIRIS-Rex, going to Bennu in 2023, CAPTEM will assemble a subcommittee. There are many issues related to Mars, and CAPTEM is beginning to think about the Mars 2020 mission.

Ongoing issues include analytical capabilities and facilities, for which CAPTEM has a standing action item to continue planning for NASA work. In the area of informatics, a community survey on data formats and practices was put on hold due to a PSD request to ARES, and this is affecting PIs. CAPTEM needs guidance, and it is unclear whether there will be PI support for data archiving. There is also an anticipated need for Mars curation facility preparation, which CAPTEM can develop despite not having a Mars subcommittee. Finally, if there are any plans to commemorate the fiftieth anniversary of Apollo 11, CAPTEM would like to be involved.

Dr. Green said that NASA is now negotiating with JAXA on a percentage of returns from Phobos. That mission launches in 2024, probably before the MSR. This is a big evolution for JAXA. Dr. Hagerty asked about the implications of the informatics definitions being on hold. Dr. McKeegan replied that there are different stages for different types of samples. It was explained that CAPTEM is probably not a good match with PDS.

LEAG

Dr. Clive Neal began the LEAG update by noting the highly successful outreach for the 2017 solar eclipse. He then presented a list of activities from the last 2 years. In 2015, LEAG established a Commercial Advisory Board, LEAG-CAB, which has regular teleconferences and an annual meeting. It has become large enough to need a new structure. LEAG represented the lunar community at the Planetary Science Vision 2050 conference in early 2017 and has been sponsoring networking events at the Lunar and Planetary Science Conference (LPSC). LEAG also has guest speakers at annual meetings.

Major findings from LEAG include the following:

1. The Resource Prospector Mission, currently in HEOMD, could benefit from SMD/PSD involvement.
2. Polar volatiles constitute a joint target for science and exploration.
3. LEAG supports expansion of SALMON to include commercial providers.
4. The moon should be seen as a strategic destination, to enable Solar System science and exploration.
5. There should be technology development for lunar sample return.
6. NASA should establish milestones to develop the cis-lunar economy with commercial partners and HEOMD.

LEAG held two “Back 2 the Moon” workshops in 2017, emphasizing stimulation of the space economy. Findings include that efficiency would come from regular trips to the moon, and there should be a dedicated lunar exploration program. The Advancing Science of the Moon Specific Action Team (ASM-SAT) was given several action themes. The AG was tasked by PSD to review progress made to address the major lunar priorities laid out in the NAS report from 2007. The objectives and goals are still benchmarks. There are three new areas for consideration: lunar volatile cycle, origins of the moon, and lunar tectonism and seismology.

NEXT-SAT, mentioned by Dr. Noble on the first day of the meeting, was created to assess the missions needed to address new lunar science questions. The Team developed a number of findings, include that there is a need for mission opportunities to address key questions, and commercial entities require assistance in becoming viable players in lunar activities. The private sector entities have yet to demonstrate that they can land on the lunar surface and return with samples.

Volatiles-2-SAT was formed in response to a NASA request to coordinate eight international missions to the lunar south pole. The full report will be available shortly, with 18 findings. Highlights are that missions should visit different sites with essential measurements made at each, and there should be a communications relay infrastructure. The lunar capabilities roadmap was about to come out, pending

review. SSERVI and LEAG co-sponsored a lunar science for landed missions report, also due soon, with five overarching themes and a number of enabling technologies. There are many opportunities to develop lunar science.

Dr. Green thanked Dr. Neal for all the work LEAG has done under his guidance, noting that NASA has asked for enormous input over the last few years, and that information was used.

MAPSIT

Dr. Jani Radebaugh, chair of the Mapping and Planetary Spatial Data Infrastructure Team (MAPSIT), explained that planetary missions generate a lot of data, and putting those data together in mosaics helps to create a realistic and useful view. She noted that the combination of geologic and derived regional and global data with the associated geospatial infrastructure is integral to the success of the planetary science enterprise. The ideal is for all users to access and use NASA planetary spatial data. The community also should be able to anticipate how to use the data. MAPSIT helps in this, seeking a path forward for laying out Planetary Spatial Data Infrastructure (PSDI) as a framework for obtaining and using the data. PDS secures and preserves data, but is not tasked with making them usable. MAPSIT strives to make data discoverable and usable. However, PSDI examples are not yet available. There is a need for standards. In the interim, MAPSIT supports the community in developing and geolocating their mosaics. Accuracy is an issue with the Titan mosaic, for example, and it is not clear who should address the issue.

The path ahead involves community input, and MAPSIT is approaching the AGs for wish lists tied back to their goals documents. There is already a Spatial Data Infrastructure (SDI) for OSIRIS-Rex, which could be a good template, and MAPSIT now has a PSDI roadmap. The goal is to help the community have spatial data that works, while supporting NASA science and exploration goals. MAPSIT wants to encourage the creation of PSDIs, but for that the Team needs input and support from the AGs and NASA, as well as stakeholder priorities.

Dr. Green said that for the moon, the TREK system has over 1,000 datasets. NASA hopes to leverage that system and would like input on how well MAPSIT members think it works. NASA has also asked the TREK team to co-register the Phobos data, which go back 4 years. These are important systems, and it is important to continue to do overlay.

Dr. Schmidt asked about the appropriate time for missions to address SDIs. She also wondered if these were broader than community goals, possibly being more like best practices. Dr. Radebaugh said that this is an ongoing issue. The Juno camera was not calibrated or geo-referenced, but the results were fantastic. Ideally, these things are in place before launch. Examples might be helpful. Dr. Green added that Juno was a PI-led mission, and PSD hopes that PIs will recognize the enormous importance of visual data. It is valuable not just for science, but also for bringing science to the public. The lessons learned from Juno should be applied. Dr. Radebaugh said that missions want to return the best data they can, and MAPSIT should be able to educate on this. Another issue is where the mosaic information goes, as funding is still slim. Dr. Mainzer said that having standards would be extremely important, as part of the archiving. She wondered if the Earth science community might have things that can be leveraged. Dr. Radebaugh agreed that they have good standards and examples. Dr. Green said that he would like to get MAPSIT recommendations on a standard format. Other divisions have standards that have been very helpful to them. Planetary science needs to move in that direction.

MEPAG

Dr. Jeffrey Johnson provided a status update on the Mars Exploration Program Analysis Group (MEPAG), which addresses Mars science goals related to life, climate, geology, and humans. MEPAG provides science input to help plan and prioritize Mars exploration activities. It is community-based and

interdisciplinary, and includes international members. MEPAG keeps its goals document updated to align with the DS, and conducts analysis activities on topics relevant to Mars-related exploration. Some of the analysis may be in response to requests from NASA and NAS. In addition to the executive committee, MEPAG has a goals committee and includes representatives from SMD and HEOMD. Recent activities included two briefings of the mid-term decadal review panel. MEPAG has decided to have more virtual meetings and teleconferences in addition to the annual face-to-face meeting. Upcoming MEPAG activities include a meet-and-greet session at the next LPSC meeting, the annual MEPAG meeting in April, and the July COSPAR meeting. MEPAG plans on identifying mission objectives and concepts for the next DS.

MEPAG has identified science questions that require further investigation. Key among these is whether Mars ever had or still has life. There is also a need to identify and characterize the habitation areas, their transitions, and their histories. Another question concerns how terrestrial planets like Mars respond to early processes. Water is a big issue on several dimensions, including water ice and the water cycle. Methane is also of interest. MSR is a high priority. New discoveries will continue, and international and commercial interests are also targeting Mars. New capabilities like Solar Electric Power (SEP) and smallsats are coming up. There are non-MSR science objectives to consider, as well. MEPAG will continue supporting the Mars 2020 rover and MSR. Mars is complex, requiring broad coordination. MEPAG will keep updating the goals document consistent with new discoveries, identify New Frontiers candidates, and prepare for the next DS.

Mars is a logical destination for humans in deep space, and that needs to be studied in terms of cost, risk, resources, hazards, and how to get there. MEPAG can assist exploring these questions. The workshops allow people to talk about these things. Concerns include the infrastructure that supports the Mars program. Dr. Johnson noted that Curiosity and Opportunity are already old, MRO is having a battery issue, and some relay providers are aging. MEPAG has not seen a high level of commitment to MSR missions, though that conversation has re-opened. Nor has MEPAG seen many flight opportunities for U.S. investigators to address outstanding science questions along with or as part of the missions required for sample return. Even the notional PSD budget shows a need to define the next Mars architecture.

MEPAG is ready to respond to NASA requests for input.

OPAG

Dr. Schmidt gave the Outer Planets Assessment Group (OPAG) presentation on behalf of her colleague, Dr. Alfred McEwen. OPAG has many charges and has been updating its goals document in order to track science priorities as they change over time. The AG is also concerned with ocean worlds. OPAG meets twice each year and has been providing science input for planning and prioritizing outer planet exploration activities. Members present at NAS studies, and OPAG documents are input to the DS panels. Along with the Small Bodies Assessment Group (SBAG), OPAG addresses issues related to Pluto and other dwarf planets.

Among key activities are the end of the Cassini mission and the selection of Dragonfly for the next step of New Frontiers competition. Juno completed its tenth flyby of Jupiter, and Europa Clipper is progressing to PDR. ESA's JUpiter ICy moons Explorer (JUICE) is moving toward a projected launch in the 2020s, and the Europa lander SDT and pre-Phase A studies have been done. The ice giants SDT was recently completed, and OPAG has been working on roadmaps to ocean worlds.

The most recent OPAG meeting was in the fall of 2017 and generated some key findings, which Dr. Schmidt summarized. First, the current outer bodies missions have been successful, and OPAG would like NASA to support more data analysis. OPAG also supports NASA's decision to proceed with the Europa lander, taking science community input. The AG would like to see a flagship mission for

exploration of ice giant systems as soon as the budget allows, with the necessary power sources and international partners. There was concern that the last Discovery AO included no discussion of RTGs. OPAG would like to work with PESTO and the RPS offices on technology. In addition, OPAG is preparing to support mission studies for the upcoming DS, and would like clarification of targets for mission studies. The AG is building connections between the outer planets and Earth oceanography communities, and encourages NASA to emphasize such connections. OPAG would like to see a PSD manager dedicated to the Data Analysis Programs (DAPs) for Cassini and New Frontiers. Finally, regarding diversity and unconscious bias, OPAG requests that NASA brief the AG on PSD's work to address this topic.

A draft goals document identifies and consolidates the top outer bodies science questions. The current outlook is much improved since November, 2015. Changes include a revised introduction, more explicit discussion of ocean worlds, and several new sections. Dr. Schmidt presented a few results since the last DS, along with a list of priorities and some remaining questions. Eight of the 10 outer body priority questions from the DS have been addressed to some extent via missions to the outer Solar System. The draft recommendations reflect the findings of the fall 2017 meeting, while also addressing smallsat missions, and life detection versus habitability.

Dr. Green said that PSD was aware of many of the recommendations and hoped to act on them. He gave examples of working with ESA on ice giants, and explained that PSD was about to hire an ocean worlds civil servant. There are liens against RPS, however, and the reinvigorated lunar program will be a factor there as well. He encouraged OPAG to consider what can be done using solar power, including with the moons of Jupiter and Trojan. NASA is working with DOE to get plutonium back into production, which could be available in 2022. Until then, NASA must manage it as a limited supply. Dr. Schmidt held that outer planet missions are not feasible with solar, especially past Jupiter. Dr. Green reiterated the need to consider solar options, adding that while missions cannot use RTGs for power, heating is possible.

SBAG

Dr. Timothy Swindle explained that the SBAG charter includes asteroids, comets, interplanetary dust, small satellites, and trans-Neptunian objects, as well as meteorites and Centaurs. The steering committee members represent a range of interests, including technology, planetary defense, and human exploration. Meetings usually focus on a specific topic. Of the ongoing missions, three are in extended phase, and there are missions in the concept and development phases as well. Discovery 13 selected Psyche and Lucy. Other missions of interest include CAESAR, NEOCam, DART, and MMX.

Findings from the last SBAG meeting, in January, 2018, include support for NASA's launch cadence in the Discovery program, as well as support for NASA and NSF in their efforts to rebuild the Arecibo observatory following Hurricane Maria. SBAG encourages preservation of APD's Wide Field InfraRed Space Telescope (WFIRST), and supports mission studies for Ceres and KBOs. In addition, SBAG would NASA to make the changes necessary to fully fund and implement the NEOCam mission. In the area of ROSES and AOs, SBAG would like to see greater transparency when there are changes. While SBAG is disappointed that RPS will not be readily available, the members applaud NASA's efforts to move forward. The AG further supports USGS studies of asteroid resources, and is eager to see the full SIMPLEx call.

The small bodies goals document is being revised to add in-space resource utilization to the existing goals. The goals document constitutes a framework for the community. SBAG plans to survey the community on priorities for the DS. Dr. Swindle showed the membership of the steering committee, explaining that SBAG tries to have diversity across multiple axes.

Dr. Roberge noted that WFIRST, an APD mission, does not have a Solar System investigation team. Dr. Swindle replied that SBAG has put together a group to develop general requirements to make astrophysics missions useful to Solar System scientists. Dr. Roberge agreed that Solar System scientists need a seat at that table. Dr. Swindle said that SBAG is trying to make Solar System science more visible, with guidelines on what is needed to make the tracking useful. Ms. Daou added that the WFIRST team has contacted some Solar System scientists. She keeps an eye on this and tries to pull in planetary scientists. In addition, Dr. Green and Dr. Paul Hertz, APD Director, often discuss this. Dr. Rall suggested that Dr. Zurbuchen be made aware of this issue. Dr. Roberge added that the FY19 PBR zeroes out WFIRST, but the team continues to work as directed. Dr. Mainzer noted Ms. Daou's efforts to increase awareness of astrophysics assets among planetary and small bodies scientists. It was suggested that PAC could encourage the Astrophysics Advisory Committee (APAC) to have a planetary member, similar to Dr. Roberge representing astrophysics on PAC.

Dr. Verbiscer noted that the two Discovery missions cited by SBAG both require RPS. She asked if SBAG shared OPAG's concern that the next Discovery AO does not include RPS. Dr. Swindle said that this is indeed a concern, but SGAG is happy to see a plan for future access to RPS. Dr. Lyons asked if OPAG and SBAG members felt compromised due to their broad agendas. Dr. Schmidt said that this can be an issue, but she was wary of fragmenting the community further. Dr. Swindle added that SBAG resisted setting priorities in the goals document.

VEXAG

Dr. Robert Grimm provided an update from the Venus Exploration Assessment Group (VEXAG). The United States is not sponsoring Venus exploration at the moment, though the science community has benefited from international missions. The last U.S. mission was in 1989, and none are planned, meaning that if a mission were to be approved immediately, it would be 35 years between U.S.-supported Venus missions. VEXAG remains active, however. Dr. Grimm listed recent meetings and presentations, includes workshops and conferences. Among these was a Venus modeling workshop. Upcoming activities include a number of reports and an international conference to be held in Japan.

The VEXAG charter states that the AG is to identify science priorities and opportunities, and convey them to NASA. VEXAG is developing and updating its guidance documents, and plans to provide priorities to the next DS. The top Venus science questions involve atmosphere, the surface and interior, and system interactions and water. Science results from international missions were presented to the mid-term assessment panel. There has also been some mapping of the surface. Technology development is a bright spot, with some good work accomplished in this area. The Venus Roadmap goes to 2050 and provides near-term, mid-term, and long-term goals.

There has been some frustration in the Venus community. Two of the five Discovery Phase A finalists in 2016 addressed Venus, but none were selected. VEXAG arranged a meeting with the SMD AA and Dr. Green, who assured the scientists that the selections were largely programmatic. However, there were then three Venus proposals to New Frontiers in 2017, and none were selected. The Venus Bridge report has been completed and will be released soon. VEXAG has asked for a flagship mission study, which has been authorized for later in the year. Several spacecraft will pass Venus en route to other destinations, and VEXAG has asked that they measure Venus as they fly by, yet only one is committed thus far. International missions have proved more promising. Venera-D, a Russian mission to Venus, includes a U.S. flight element as well as a joint SDT. ESA's EnVision mission is on hold, but JAXA's Akatsuki mission continues operating, with a likely extension to 2021.

The Venus Bridge report is the outcome of an AA inquiry about what Venusian science might be done for $200 million. VEXAG assessed useful science or technology demonstrations that could be within that cost cap. There have been separate design studies by GRC and JPL. Venus Bridge means to be a

pathfinder to get scientists working on Venus soon, but there is a need for larger, more capable missions. The path forward is to understand the value and viability of smallsat missions, prepare for the next DS, continue meeting, and follow the AA advice to compete. However, Venus scientists have competed and not been selected, so they need to know what else to do. Venus is a key in planetology, and NASA should study it. The community is optimistic, they have mature concepts, and they need advocacy.

Dr. Green explained that NASA management met with JAXA earlier that week, and both space agencies are cost-constrained. However, NASA told JAXA that the Atazuki mission is important to NASA, and NASA wants to increase its support. No decision has been announced regarding an extension, but NASA is ready to accommodate discussion and enhance the Agency's participation.

Dr. Roberge asked if VEXAG had thought about exo-Venuses, which she expects to be discovered. Dr. Grimm said that this was a topic of interest, and some exoplanet scientists participate in VEXAG. They want to cross the bridge with astrophysics. The measurements need to be in the VEXAG goals document, which should explain the link to exoplanets. Dr. Lyons agreed that there is tremendous opportunity with alternative Venuses. When Dr. Roberge mentioned models of early Venuses, Dr. Lyons observed that Venus is the fate of all planets in the habitable zones. Dr. Roberge added that there may be some renewed interest in Venus from the astrophysics community.

Q&A

Dr. Roberge noted OPAG's concern about the loss of ultraviolet capabilities with the eventual end of the Hubble Space Telescope (HST). She asked about crossing the divisional boundary to astrophysics. Dr. Schmidt provided two examples. First, Dr. Green worked to get HST time to study plume activities and do KBO surveys. In addition, the astrophysics DS had members of the planetary community on its science and technology definition teams (STDTs). Dr. Verbiscer asked about getting new, dedicated ground-based telescopes. Dr. Schmidt replied that they are expensive. Dr. Mainzer added that if there are not sufficient numbers of proposals from a community, it gets a smaller fraction of the total time and it then appears that the community is penalized. Dr. Schmidt explained that the HST time allocation process has another quantity bias, such that the more orbits a PI seeks, the more he or she gets. This puts some communities at a disadvantage, in turn leading to interest in dedicated telescopes. Dr. Mainzer thought the communities should work on how to obtain more allocation. She wants to make sure that investigators get what they need from any new telescopes. Ms. Daou explained that the planetary community does not generate a lot of these proposals. She offered to help the community on this.

Discussion

Dr. Verbiscer explained that for the PAC findings and recommendations, the Committee would discuss material for the drafts, then finalize them via email. She began a preliminary list of topics to discuss:

- MSR grab or contingency sample;
- Lack of standardization for Geographic Information Systems (GIS);
- Coordination and standardization of planetary data for inter-operability and discovery;
- PAC wants to see the PDCO data for progress on identification of NEOs the size of those Congressionally mandated, and smaller;
- Mercury is not represented in an AG, and should have its own AG. The Mercury community is growing and has a mission;
- The RPS issue is significant and there is community concern;
- There should at least be a conversation to help the Venus community strike the right chord;
- Support for sustainable moon investment and a lunar exploration office;
- Commercial connectivity;
- The ECF Program is a topic of concern and could be strengthened;

- The Origins Program and fieldwork might have fallen through the cracks in R&A restructuring. This also might be an interdivisional issue. Opportunities might be missed at the pre-planetary stage;
- Emerging Worlds could be interdivisional, but that requires funding from both sides. Origins was cross-divisional, and SMD needs to restore this;
- Have a planetary person on APAC;
- Better inform Solar System use of astrophysics assets;
- Make calls broad enough to encompass interdivisional proposals;
- Are research results from interdisciplinary efforts like NAI getting into technology and missions? Address the propagation of astrobiology science into technology development, missions, and instrumentation;
- APD has technology development roadmaps for each Program Analysis Group (PAG), which might warrant a look;
- Commercial entities and planetary protection.

It was determined that standardization of GIS was simple and could be addressed via email. Dr. Rall said that as long as PAC agreed to the content of findings and recommendations during the meeting, fleshing out details via email is not a problem. He would monitor the emails carefully.

Findings and Recommendations Discussion

Dr. Verbiscer began the discussion of topics that required more work during the meeting.

ECF

PAC first addressed ECF Program revision and restoration. Dr. Schmidt raised the issue of whether ECF awards were supposed to help the recipients get hired. If so, the fellowships should be available before the fellows have their jobs. Currently, candidates must win a ROSES grant first, which could eliminate good candidates whose institutions do not allow them to be PIs. In addition, not all planetary scientists are at tenure-granting institutions, so not all awardees can or do use the funds. The intent was to help get faculty jobs, and the program should reflect that.

Dr. Mainzer said that hiring committees at some institutions want to see that the applicants have funding. Dr. Schmidt was concerned that some employees are not eligible since they do not have faculty jobs. She and Dr. Roberge did not think the ECFs should be associated with ROSES grants. Dr. Mainzer wondered if there might be a legal consideration behind this. Dr. Filiberto said that his institution will not let postdocs become PIs because of pay structures and not wanting to cover the gap. Dr. Lyons observed that it is very institution-specific, and Dr. Rall said that the award is not a fixed amount.

Dr. Hagerty explained that he was not allowed to use his ECF on salary. It should be allowed for that. Drs. Schmidt and Rall suggested having the ECFs operate more like the Hubble Fellowships, which are set up after the applicant is at an institution. It was agreed that PAC supported modeling the ECF after the Hubble Fellowship, which can travel with the person from one institution to another. It does affect budgeting, however. There were also comparisons to the NASA Postdoctoral Program (NPP) fellowships. These are applied for openly and set up after the recipient arrives at an institution. The NESSFs are another model in which the funds belong to the individual. It was noted that institutions do not want to be obligated, and some universities are skittish in regard to legal issues.

Dr. Rall said that the ECF program has been suspended for a year, and he was not sure PAC had enough material for a finding. It was observed that they were stuck on how to support early career people. Dr. Rall pointed out that NPP is for those without jobs, and the NSF Faculty Early Career Development (CAREER) Program gives awards to individuals who have jobs already. Dr. Schmidt noted that the

requirements are different for NSF CAREER applicants submitting through their universities. Dr. Rall explained that if PSD were to have two separate programs, they will still come from the same funding line and the panels can evaluate them at the same time. Dr. Stroud reminded PAC members that government laboratory personnel need to be eligible. Dr. Rall said that PSD could address the possibility of double-dipping. Dr. Schmidt cautioned that PAC was changing a lot about the program. She was wary that they had not discussed it sufficiently and were dealing with multiple issues. Dr. Filiberto agreed that they were not going to finalize anything at this meeting. It was noted that the NSF CAREER award for tenure track fellows does not fund most of what they were discussing. Dr. German reminded PAC that PSD was not spending the funds as allocated, necessitating a change. He wanted to look further at NPP for pre-position people, and at NSF CAREER-like awards for the people who already have jobs.

Dr. Filiberto said that using the current ECF style on proposals would not require extra effort. Dr. Rall said that removal of the tenure requirement would make it easier, as it would open up eligibility. It was agreed that that is acceptable. Dr. Mainzer said that while the transition to tenure is important, a large portion of the planetary community does not work for tenure track organizations. Dr. Schmidt noted that the original emphasis was to help planetary people get into the tenure situations where they had not previously been considered. Dr. Stroud thought that there was general agreement among PAC members to have the Universities Space Research Association (USRA) administer an NPP-style fellowship for those without a faculty job, while NASA should look at how to administer a tenure-track fellowship program.

MSR

Dr. Verbiscer asked PAC to discuss post-Mars 2020 MSR. Dr. McCubbin observed that the "lean MSR strategy" that Dr. Watzin described did not include a "grab" or contingency sample. Mission success versus failure is based on whether the mission brings back something. Any sample will be scientifically interesting, so the retrieval rover needs to be able to grab a sample in case the planned cache retrieval has problems. Dr. Filiberto added that the first thing the Apollo astronauts did on the moon was put a rock in their pockets because then they would have brought back something no matter what. Dr. McCubbin reiterated his point that there is a need to ensure that there is a sample to bring back.

For the working draft finding and recommendation, PAC wrote the following:

- The lean sample return strategy did not include a contingency sample. Returning anything has been a mission success criterion for other missions.
- PAC recommends collecting a simple, contingency grab sample with a curation plan.

It was agreed that the grab strategy should be as minimal as possible, with the general message to PSD that MEP should think about doing something more.

Astrobiology Infusion/Technologies

Next, PAC addressed how to infuse astrobiology R&A into mission design and development. Preliminary draft findings were:

- NASA should address how propagation of astrobiological science and technology feeds into development for missions.
- There is a concern about how to get more integration into mission activities. Progress is being made with exoplanets.

Dr. Schmidt said that it comes down to mission and instrumentation selection, and Dr. Roberge held that astrobiology should be more strongly influencing the technology development programs. She did not see it as an NAI problem. Dr. Lyons pointed out that organic geochemistry has been considered in OSIRIS-Rex and other missions. Dr. Schmidt said that it was not the same as astrobiology, and there are still issues. PESTO, for example, emphasizes technologies that get payloads to planets, not what gets detected.

She would like more funding for detection systems. Some missions are considered higher risk because their science is hard to review. There are technology demonstrations, but they are still considered risky.

Dr. Stroud described CAESAR and Dragonfly as being astrobiology-oriented. Dr. Schmidt made the point that while things are happening, the hardest questions are not being answered. The priorities for technology development programs seem to be set by the larger programs. Dr. Rall agreed, adding that Dr. Voytek made the case about her priorities. Dr. Schmidt said that there needs to be a lot of activation activity over time. There is a risk that some priorities are dropped when selecting technology and missions. She perceives a bias, though she did not believe it to be conscious. Dr. Lyons thought that a problem exists, though it is hard to pinpoint. He also thought that NAI might not have a lot of technology expertise.

Dr. Roberge described how APD and its PAGs address technologies, including technology gap lists. Dr. Rall described how technology and instrument development are infused into PSD missions. It involves long-range work. Dr. Schmidt pointed out that NAI seemed to think that the Institute does not have the influence they want. She asked if the astrobiology technologies should be developed as high priorities. Dr. McCubbin observed that some of the cleanliness requirements result in the rovers seeking fossilized life. When Dr. Roberge stated that the APD PAGs are more involved in technology prioritization, Dr. Schmidt added that there is not an astrobiology AG. A concern is that the instruments are not designed for astrobiology. She was not sure if a finding would be helpful or if there might be a need for more information and discussion. Dr. McCubbin said that the Planetary Science and Technology Through Analog Research (PSTAR) Program can increase the TRL. However, missions require TRL6, and the technologies are not always ready. Dr. Roberge said that APD develops plans on how to get to TRL6. If the really important technologies are not ready when needed, there is something wrong with the technology development process. That should be a finding. Dr. Stroud said that the next meeting should have a presentation on the technology development program and NAI.

Mercury
Next, Dr. McCubbin raised the issue of Mercury, which he said should have its own AG. Dr. Filiberto agreed, stating that the Mercury community does not belong in VEXAG. The Mercury community is larger than the Venus Community. There was no strong disagreement on having a Mercury AG.

RPS
RPS in Discovery for outer planets was the next topic for findings and recommendations. Dr. Rall explained that PSD owns the group that does the plutonium production. It is coming online and will ramp up to 1.5 kg per year. There is an argument that there is not enough to use now. PAC drafted the following preliminary findings and recommendations for discussion purposes:

- PAC recognizes that there are liens against the current supply of PU-238 and that this is limiting.
- PAC encourages the continued restarted production of PU-238.
- PAC would like to see the Discovery Program open to all destinations and targets, regardless of power supply requirements. The Discovery Program should allow the use of RPS if the supply of PU-238 is sufficient to support a mission that uses RPS.

Dr. Rall explained that PU-238 takes a while to produce and has to rest for a time. Dr. Hurley said that there are many good missions that could be proposed. Dr. Mainzer replied that there is some sensitivity to writing proposals for something that might not work. Dr. Stroud noted that PU-238 is important for some lunar missions, too. Dr. Hurley pointed out that there are things that can be done without it. She was wary about pushing on this and ending up in a situation where NASA will not let a selected mission fly. Dr. Schmidt noted that there is a section of the community that cannot propose due to this situation. Outer planets missions still must prove they can do the science in the first place. While Europa Clipper is in

development, there are PI-class missions that cannot be done. It does affect the teams that have made plans and want to apply again.

Dr. Rall explained that the main issue on PU-238 production is time; it is produced very slowly. He asked if PAC wanted to go forward with this, adding that Dragonfly takes fewer MMRTGs than CAESAR. It was noted that Dr. Green is holding some RPS for lunar night activities that are yet to be selected. Dr. German asked what information the DS panel would need to assess supply and demand for PU-238. Dr. Schmidt said that PU-238 is singularly enabling for outer planets missions, as there are not enough photons for solar to work further out. The lien keeps outer planets projects from accessing it. Dr. Rall said that the lien is based on both current and future holdings. It is part of the policy of opening up the Discovery Program and RPS. Dr. Hurley said that if RPS is available, it should be available to all of Discovery. She asked how an institution might support a proposal that might not be eligible for selection. PIs need the rules in advance. Dr. Mainzer asked if there is enough PU-238 to support the next Discovery call. Dr. McCubbin maintained that it should not be in the call unless the PU-238 is available. Dr. Schmidt said that this should be a high priority.

Venus

The next topic was Venus. Dr. Filiberto said that the Venus community, of which he is a part, has done a very poor job of selling themselves. NASA needs a Venus mission, but the community has not made it exciting. There are a lot of interesting things about Venus, such as the atmosphere, terrain, ancient crust, and past habitability. Dr. Lyons agreed, noting that the Venus-to-Mars range of the Solar System is fascinating, and Venus is a great analog to Earth. There is a compelling story about how Venus lost habitability. Dr. Roberge observed that without the information gathered from a Venus mission, it is not clear that ancient Mars was more habitable than ancient Venus. Dr. Filiberto said that there are lost opportunities, but it was not clear how that might be a PAC finding. Dr. McCubbin suggested stating that the Venus community should coalesce around a common set of goals. Dr. Filiberto replied that it is hard to tell the community that.

Dr. Stroud came up with the following wording, which PAC used as a working draft for its finding:

- Venus opportunities are lost in Discovery and New Frontiers.
- PAC recognizes that Venus remains an important, under-investigated target with huge potential, and recognizes its connections to exoplanets and habitability.

R&A Origins Program

Discussion turned to the Origins Program. Dr. Filiberto said that he had talked to Dr. Jeffrey Grossman, who said that PSD is addressing the gap. He explained that Dr. Grossman does not think it should be an interdivisional program. Such proposals are welcome in Emerging Worlds. Dr. Stroud noted that the interdivisional component has to go to the right division. The ROSES language handles the gap in funding opportunities for people who are primarily solar. It was not clear whether PSD had focused opportunities for interdisciplinary and interdivisional components for origins. She just wanted to know, and said that this was another reason for APAC to have member from planetary science.

The draft findings about the gap introduced by the R&A restructuring of the Origins Program were:

- Field work not associated with PSTAR has not found a comfortable home and has been underfunded.
- PAC would like to see the results of a keyword analysis specifically comparing Astrobiology Science and Technology for Exploring Planets (ASTEP) with PSAR and Habitable Worlds with Planetary Geology and Geophysics (PPG) and SSW.

Dr. Morris explained that the proposals will find a home, but the proposer must make the case in the direction of the program to which he or she is proposing. Dr. Stroud's construct of Emerging Worlds for a process-oriented proposal and the Exoplanet Research Program (XRP) for object-oriented proposals might work. However, she does not think that way. If there is a question, proposers can call and talk to the program manager. The proposal will not go to the panel stage without being reviewed.

Dr. Filiberto noted that field work not associated with a mission or technology development has not found a comfortable home. Dr. McCubbin asked if this were a program or community issue. If the latter, it was outside of what PAC could address. Dr. Filiberto replied that is was the latter, and the community needs to accept that it goes in certain areas. Dr. Hagerty asked if it might be underfunded. There is a perception, but he was not sure if it was an actual issue. Dr. Rall did a quick keyword search and found that the funding has decreased in field work, but it has been partly offset across programs. Dr. McCubbin said that PAC needed more information.

Although a few draft points were submitted for additional work, Dr. Green suggested that PAC address access to astrophysics assets by Solar System researchers at the next meeting, when PSD can provide some answers. Dr. Verbiscer added it as a future agenda item and removed it as a finding.

Adjourn

The meeting was adjourned at 3:58 p.m.

Appendix A
Attendees

Committee members

Anne Verbiscer, University of Virginia, *Chair, Planetary Science Advisory Committee*
Jonathan Rall, NASA, *Executive Secretary*
Lynn Marie Carter, University of Arizona
Robin Mihran Canup, Southwest Research Institute
Justin Filiberto, Southern Illinois University – Carbondale
Chris German, Woods Hole Oceanographic Institute
Justin Hagerty, U.S. Geological Survey
Dana Hurley, Johns Hopkins Applied Physics Laboratory
Timothy Lyons, University of California – Riverside
Amanda Mainzer, Jet Propulsion Lab
Francis McCubbin, NASA Johnson Space Center
Aki Roberge, NASA Goddard Space Flight Center
Britney Schmidt, Georgia Institute of Technology
Rhonda Stroud, U.S. Naval Research Laboratory

NASA attendees

James Green, NASA HQ, *Director, Planetary Science Division*
Maria Banks, NASA GSFC
DaMara Belson, NASA HQ
M. D. Bicay, NASA ARC
Doris Daou, NASA HQ
Kelly Fast, NASA
Robert Fogel, NASA HQ
Ed Gragzeck, NASA GSFC
Jeff Grossman, NASA HQ
Lindsay Hays, NASA HQ/JPL
Lindley Johnson, NASA HQ
John Karcz, NASA
Michael Kelly, NASA HQ
Jared Leisner, NASA HQ
Rebecca McCauley Rench, NASA
Michael Meyer, NASA HQ
Tom Morgan, NASA GSFC
Marc Neven, NASA HQ
Michael New, NASA HQ
Sarah Noble, NASA
Adriana Ocampo, NASA
Lisa Pratt, NASA HQ
Christy Rivera, NASA HQ
Mitch Schulte, NASA HQ
Tom Statler, NASA
Mary Voytek, NASA

Non-NASA attendees

David Gump, Deep Space Industries
Grace Hu, OMB
Jeffrey Johnson, Johns Hopkins University/APL
Joseph Lazio, JPL
Steve MacDonald, USRA
Kevin McKeegan, UCLA
Lindsay Milliken, Lewis-Burke Associates

Louise Procter, LPI
Jani Radebaugh, BYU
Amy Reis, Zantech
Elizabeth Sheley, Zantech
Timothy Swindle, University of Arizona
Paul Vooser, Science
Ashlee Wilkins, AAS
Ana Wilson, Zantech

WebEx participants

Brent Archinal
Brad Bailey
Jaya Bajpayee
Linda Billings
Julie Castillo
Stephen Clark
Dan Crichton
Leonard David
Dwayne Day
Brett Denevi
Rajani Dhingra
Howard J. Eisen
Jeff Foust
Marc Fries
Kristina Gibbs
Jeff Grossman
Victoria Hipkin
Noam Izenberg
Jeffrey Johnson
Gordon Johnston
Michael Kelley
Rachel Klima
Simone Marchi
Rebecca McCauley
Alfred McEwen
Melissa Morris
Diane Pugel
Kim Reh
John Rummel
George Schmidt
Abigail Sheffer
David H. Smith
Marcia Smith
Paul Steffes
Will Thomas
Paul Voosen
Alexandra Witze
Jenna Zink

Appendix B
Membership Roster

Anne Verbiscer, Chair
University of Virginia

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

Lynn Marie Carter
Department of Planetary Sciences
University of Arizona

Robin Mihran Canup
Southwest Research Institute

Justin Filiberto
Department of Geology
Southern Illinois University – Carbondale

Chris German
Department of Geology and Geophysics
Woods Hole Oceanographic Institute

Justin Hagerty
Astrogeology Science Center U.S. Geological Survey

Dana Hurley
Planetary Exploration Group
Johns Hopkins Applied Physics Laboratory

Timothy Lyons
University of California – Riverside

Amanda Mainzer
Jet Propulsion Laboratory

Francis McCubbin
NASA Johnson Space Center

Aki Roberge
Exoplanets and Stellar Astrophysics Laboratory
NASA Goddard Space Flight Center

Britney Schmidt
School of Earth and Atmospheric Sciences
Georgia Institute of Technology

Rhonda Stroud
Materials Science and Technology Division
U.S. Naval Research Laboratory

Appendix C
Presentations

1. Planetary Science Division Status Report, James Green
2. Lunar Discovery and Exploration Program, Sarah Noble
3. Planetary Science R&A Update, Jonathan Rall
4. Review of NASA's Planetary Science Division's Restructured Research and Analysis Programs, Steve Mackwell
5. R&A Charge to SMD Advisory Committees, Michael New
6. Mars Exploration Program Update, James Watzin
7. Joint Workshop on Induced Special Regions, Michael Meyer
8. NASA's Planetary Data System Status and Future Plans, Thomas Morgan, Maria Banks
9. *The Deep Space Network*, Joseph Lazio
10. NASA Astrobiology Institute, Mary Voytek
11. NASA's Solar System Exploration Research Virtual Institute (SSERVI), Sarah Noble
12. Ceres Pre-Decadal Science Definition Team, Michael Kelley
13. Planetary Defense Coordination Office, Lindley Johnson
14. CAPTEM, Kevin McKeegan
15. LEAG, Clive Neal
16. The Importance and Challenge of Building a Planetary Spatial Data Infrastructure: MAPSIT, Jani Radebaugh
17. MEPAG, Jeffrey Johnson
18. OPAG Update to PAC, Britney Schmidt
19. SBAG, Timothy Swindle
20. VEXAG Update to the Planetary Advisory Committee, Robert Grimm

Appendix D
Agenda

Planetary Science Advisory Committee Meeting
February 21-23, 2018
NASA Headquarters
Washington D.C.

Wednesday, February 21, 2018, 8:00 a.m – 5:00 p.m. (5H41)

08:00	Opening, Announcements	(J. Rall)
08:10	Ethics Training	(K. Spear)
09:10	Welcome from DD	(J. Green)
09:20	Around the Table Identification	(A. Verbiscer, J. Rall, & All)
10:00	Break	
10:15	PSD Status Report + Q&A	(J. Green)
11:30	Lunar Program	(S. Noble)
12:30	Working Lunch Introduction of AA, Dr. Thomas Zurbuchen	
1:30	PSD R&A Status	(J. Rall)
2:00	R&A Restructure Review	(S. Mackwell)
2:30	PSD R&A Response to Review	(J. Rall)
3:00	Break	
3:15	SMD R&A	(M. New)
3:45	Discussion	ALL
5:00	Adjourn	

Thursday, February 22, 2018, 8:30 - 5:00 p.m. (5H41)

8:30	Agenda Updates & Announcements	(A. Verbiscer, J. Rall)
9:00	Mars Update	(J. Watzin)
10:00	Planetary Protection Officer Meet & Greet	(L. Pratt)
10:15	Joint Workshop on Induced Special Regions	(M. Meyer)
10:45	Break	
11:00	Planetary Data System	(T. Morgan)

11:30	Deep Space Network	(J. Lazio)
12:00	Lunch	
1:00	NAI & NExSS	(M. Voytek)
2:00	SSERVI	(S. Noble)
2:15	Ceres Definition Team	(M. Kelley)
2:30	Planetary Defense Coordination Office	(L. Johnson)
3:00	Findings and Recommendations Discussions	(All)
5:00	Adjourn	

Friday, February 23, 2018, 8:30 - 5:00 p.m. (5H41)

8:30	Agenda Updates & Announcements	(A. Verbiscer, J. Rall)
9:00	CAPTEM	(K.McKeegan)
9:20	LEAG	(C. Neal)
9:40	MAPSIT	(J. Radebaugh)
10:00	Break	
10:20	MEPAG	(J. Johnson)
10:40	OPAG	(A. McEwen)
11:00	SBAG	(T. Swindle)
11:20	VEXAG	(R. Grimm)
11:40	Q&A	
12:00	Lunch	
1:00	Discussions	(All)
2:00	Findings and Recommendations Discussions	(All)
5:00	Adjourn	