NASA ADVISORY COUNCIL

Planetary Protection Subcommittee

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NASA Headquarters
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MEETING MINUTES

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Robert Lindberg, Vice Chair

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Gale Allen, Executive Secretary

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May 20, 2014

Introduction

The Executive Secretary of the Planetary Protection Subcommittee (PPS) Dr. Gale Allen, made preparatory announcements. Vice Chair of PPS, Dr. Robert Lindberg served as Chair in the absence of Dr. Eugene Levy. In addition, the planned briefing on the Space Studies Board (SSB) Subcommittee on Astrobiology and Planetary Science was to be covered by Dr. Catharine Conley, Planetary Protection Officer (PPO), in lieu of Dr. Levy. Introductions were made around the meeting room.

COSPAR

Dr. Conley and Dr. Gerhard Kminek co-briefed the PPS on the most recent biannual Committee on Space Research (COSPAR) scientific assembly, held in August 2014 in Moscow.

Dr. Kminek reported the results of the COSPAR panel meeting on PP, comprised of three half-day sessions on various aspects of PP, including research and development (R&D) support for missions. There were presentations of the results of two COSPAR colloquial workshops on Phobos sample return and special regions. There were also reports from a number of missions representing NASA, Japan Aerospace Exploration Agency (JAXA), Roscosmos and the European Space Agency (ESA). The meeting was well attended by over 2300 registered participants. The Planetary Protection Panel (PPP) accepted 36 abstracts, 6 of which had to be withdrawn due to travel restrictions. COSPAR elected a new president and modified the panel composition. The terms of PPS members Drs. Conley and Victoria Hipkin were extended, and a new vice chair from JAXA was added, Dr. Hajime Yano. Dr. John Rummel stepped down as the Chair of the PP panel at COSPAR, and was replaced by Dr. Kminek. The next scientific assembly will be held in 2016 in Istanbul, Turkey, at which there will be two dedicated workshops to review current PP requirements, and to establish new requirements if necessary. The first workshop will be on Mars special region requirements, and the second will address the more technical details of implementing PP requirements for human missions. A clear need has been identified for the latter. The first workshop is planned for the first half of 2015, and the second in the latter half, so as to provide sufficient time for their respective outputs to be discussed at the assembly in 2016. A proposal for holding the 2018 scientific assembly in Pasadena, CA was accepted.

COSPAR is adding a new panel that will deal with general life detection, both for astrobiological targets and planetary protection, for icy body sample return. A special issue of Advances in Space Research, "New Challenges for Planetary Protection," is to be published on the subject of sample return and related issues. The deadline for submissions is 28 February 2015, and submissions will not be limited to presentations from COSPAR. Any questions regarding the issue can be addressed to Dr. Kminek, or via email to Ms. Peggy Ann Shea at sssrc@msn.com.

The second COSPAR symposium is to be held in Brazil in November 2015, and will focus on Water and Life in the Universe, encompassing the subjects of astronomy, water on Earth and exoplanets, how to measure water via remote sensing, and atmospheric science. The Panel on PP will hold an interdisciplinary presentation on planetary protection on watery worlds and icy bodies (Enceladus, Europa). Submissions may be made from March through May 2015 submission.

Panel issues discussed at the recent meeting included the first update of PP requirements for Mars Sample Return (MSR). A Mars Exploration Program Analysis Group (MEPAG) report is currently in press on this subject, and will be reviewed jointly by the National Research Council (NRC) and the European Science Foundation (ESF). Based on the interest from the science and user (space agencies) communities CoSPAR will also support a refinement of requirements for human missions, and for sample return from Outer Planet satellites. COSPAR is now including Japan in the Planetary Protection Panel leadership, and has invited Russia to join the Scientific Organizing Committee. There is a continuing effort to get India and China on board.

Pertinent panel issues include reaching out and communicating the message of PP, as well as a simplification of the process for submitting pre-launch documentation to COSPAR; there are more players outside the government, and COSPAR wishes to ease the submission of information to have it properly documented. There was some discussion of holding PP courses in China, Russia and Japan. COSPAR has ongoing communication with the Netherlands-based Mars-One project, which is planning a robotic mission for 2018 and involves a contract between Lockheed Martin and a UK company. The project has finished some mission definition work and is awaiting financial backing, expected by January 2015. Payload selections will be announced at that time. The project includes both science and academic payloads. COSPAR has also started formal communications with the United Arab Emirates (UAE) and has invited them to participate in PP courses. Dr. Peter Doran commented that he is running the Astrobiology conference in Chicago and encouraged submissions to this international conference.

Planetary Protection at NASA

Dr. Conley reported on the latest PP activities within NASA, and reviewed the science goals of PP, which are to support science and other human interests, to ensure good science, and to avoid interfering with future science, according to NASA Policy Directive (NPD) 8020.7G. Special requirements for robotic missions are embodied in NASA Policy Requirement (NPR) 8020.12D. A new document, NPI 8020.7, governing PP for human extraterrestrial missions, was released to the NASA document system NODIS in May. Dr. Lindberg requested that copies be distributed to the PPS membership.

Dr. Conley reviewed Space Treaty obligations as they relate to COSPAR. The Space Studies Board (SSB), the US organization parallel to the international structure, is formally the national representative to COSPAR. Dr. Conley interacts with the SSB.

Public comment and discussion of recommendations are facilitated through COSPAR's Panel on Planetary Protection. Outside of NASA, policy is driven via the United Nations, as well as numerous federal agencies such as the State Department, Centers for Disease Control (CDC), and the White House Office on Science and Technology Policy (OSTP). Implementation and regulation is carried out through the Federal Aviation Agency (FAA) and Commerce Department. The agencies cooperate and coordinate through Letters of Agreement.

Dr. Conley reviewed the role of PPS of providing advice on planetary protection to NASA, making recommendations on implementation, points of policy, and guidance on programmatic issues. PPS also serves as a mechanism for interagency coordination within the US government and between international organizations.

NASA's responses to recent PPS recommendations are in work at various levels. In response to concerns about PPO staffing levels, as well as inclusion of PP issues in the Office of the Chief Engineer (OCE) Lessons Learned study on the Mars Science Laboratory (MSL), the Agency is responding with ongoing efforts. A recommendation to include the PPO early in mission planning and design is in work, and is in evidence in early work with the Mars 2020 mission. Efforts to respond to a recommendation of the placement of the PPO outside the Science Mission Directorate (SMD) are also under way. There were no formal recommendations from the November 2013 and May 2014 PPS meetings. Dr. Lindberg mentioned having had several agenda items regarding technology investments for PP. Dr. Conley confirmed that there have been no formal recommendations, but acknowledged some prior expressions of concern by PPS on technology development.

As to PP for Humans on Mars, NASA policy instruction is in place; human mission requirements are now under development by the Human Exploration and Operations Mission Directorate (HEOMD) and SMD. These requirements are characterized by a phased approach: be careful (in exploration activities) early, and tailor later constraints using knowledge gained. Searching for Mars life will become more difficult as more Earth contamination is introduced via human missions. Future colonization could be challenged if unwanted Earth invasive species are introduced. Essentially, the Outer Space Treaty states that the goal is to protect the Earth and avoid harmful contamination on Mars, both to preserve life and to protect scientific data, and avoid both false positives and false negatives. Ongoing work in this area is being performed by Dr. James Johnson at Johnson Space Center (JSC).

The response to the MSL LL study has been initiated. SMD is expanding PP training options (overseen by Dr. Andy Spry at the Jet Propulsion Laboratory) and is improving cross-directorate coordination through Dr. Johnson at JSC; SMD is still working to acquire and retain staff, and is working closely with missions in development.

The PP budget is flat. Dr. Conley was unable to fund any proposals from a PP research call in 2013. Research and Analysis (R&A) and programmatic activity funding is supported by a total of $2.5M; it is important to note that programmatic funding is about 3/5 of the total budget. There are many issues in flux, including the position of PPO.

The PPO is continuing much interaction with planetary missions, including the Cassini-Huygens Extended Mission; Cassini mission still needs to be controlled to protect Titan and Enceladus as the spacecraft flies through the rings to eventually impact Saturn in 2017. The New Horizons mission will encounter Pluto next year; it is conceivable that there might be liquid water in the Pluto/Charon system. The mission has been asked to assess this possibility through impact avoidance planning, which is currently under review. The Juno mission has been re-evaluating their impact avoidance (of Europa) trajectories; PPS will hear about this at the next meeting. OSIRIS-REx has an unrestricted Earth return categorization; PPO is evaluating controls and blanks for tracking organic Earth contamination. The MESSENGER spacecraft is still returning data from Mercury. The Gravity Recovery and Interior Laboratory (GRAIL) spacecraft impacted the Moon in 2012, at the Goldschmidt Crater near the northern polar region (75.6N); data from GRAIL will be reported to COSPAR. It has been determined that the Dawn spacecraft will not impact asteroid Ceres due to orbital mechanics constraints. The most recent Discovery selection, Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight), will demonstrate by observation and analysis that the mole will not contact Mars special regions. Mars missions this decade include the ESA Trace Gas Orbiter, Mars 2020, Mars Organic Molecule Analyzer (MOMA), and the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission, the latter of which recently entered orbit at Mars. MAVEN has successfully demonstrated its PP requirements at Mars. The Indian Space Research Organization's (ISRO) Mars Orbiter Mission (MOM) is on track; PPO would like to have an ISRO rep as an *ex officio* rep on PPS, and efforts are under way to achieve this. There is no NASA science contribution to ISRO, although NASA resources are being used to provide navigation and communications support but there is potential future cooperation on science results.

Results from the MSL rover Curiosity continue to educate researchers about the habitability of Mars. The Sample Analysis at Mars (SAM) instrument has detected organic compounds, but questions remain about the presence of terrestrial carbon and martian oxychlorine compounds (e.g. perchlorate); SAM has detected water evolving from several samples at 150°C and above. Dynamic Albedo of Neutrons (DAN) instrument results are suggesting a multi-layer structure for subsurface water distribution (1-4%) in the upper 60 cm of the Mars surface (DAN is detecting neutron-absorbing elements and is essentially measuring hydrogen bonding). The Rover Environmental Monitoring Station (REMS) instrument has detected ground surface temperatures of 20°C to -95°C over numerous diurnal cycles. This and related data from MSL may be found at spaceflight101.com. Dr. Hipkin commented that the observed measurements of relative humidity may actually be quite small.

Dr. Kminek noted that a recent presentation at the CoSPAR Scientific Assembly showed good correlation between SAM and DAN data.

A new traverse has been planned for Curiosity to minimize further wheel damage, en route to a raised riverbed at which dark streaks have been observed, based on HiRise imagery. The streaks may represent recurrent slope lineae (RSLs), an area of concern for PP.

A PP framework has been determined for the Mars 2020 mission. It will be a Category IVb mission, reflecting the use of *in situ* biosignature detection instruments, which are stand-off instruments that can detect organics at a PPM-level sensitivity. Mars 2020 has landing constraints similar to MSL due to the inclusion of a radioisotope thermal generator (RTG). The sample caching system to be included on the rover will invoke compliance with outbound requirements on a Category V Restricted Earth Return. This has not been done before. Viking, NASA's only previous Category IVb mission, is being used as a precedent. Earth Safety Assurance is the highest priority for sample return, thus significant documentation and oversight will be needed to inform Earth Safety analyses. Based on the Viking and ExoMars experience, PP has directed missions to provide clean hardware that can be verified as to its cleanliness levels at the pre-launch point, and to then implement recontamination prevention approaches, such that sample processing at the target can be done without exceeding the accepted limits on sample contamination. These limits are governed by both science and planetary protection requirements, to ensure high confidence of both scientific data and confirmation of cleanliness. An SSB meeting of experts in May 2014 (overseen by the PPS and NRC) reviewed the progress of an Organic Contamination Panel (stood up by the MEP) that was chartered with four tasks, leading to a goal of a single PP/science cleanliness requirement, to be made available at the Systems Readiness Review (SRR) milestone, minus 1.5 months. A final report from the OCP will be issued by the MEP Science Organization Contamination Science Study lead with PPS-SSB oversight ongoing into 2015.

Dr. Conley mentioned that Ms. Joanne Gabrynowicz, a PPS member, presented testimony before Congress on Space Law, and mentioned PPS recommendations on how to regulate commercial space. Dr. Lindberg requested that a transcript of her testimony be distributed to the PPS.

Dr. Lindberg raised discussion points to be revisited as possible findings for the subcommittee: the rise of commercial actors (Mars One) in space exploration; the standing of NASA and the US stand relative to ESA with respect to back-contamination and human exploration policy; SAM/DAN results and implications for habitability re: MSL traverse; and Mars 2020 categorizations with possible attendant technology gaps. Dr. Hipkin mentioned that she would be involved in preparing a white paper on international human exploration, representing an opportunity to insert timely PP concerns.

Planetary Science Division Update

Dr. James Green, Division Director of the Planetary Science Division (PSD), provided a briefing on PSD's recent activities. There has been much planetary mission success with MAVEN in orbit, the encounter with comet Siding Spring at Mars, Curiosity's arrival at Mt. Sharp, and the successful ESA Rosetta mission. JAXA will be launching Hayabusa 2 to rendezvous with the 1999 JU_3 asteroid, and is planning an exchange of samples with NASA. NASA has begun discussions with ISRO on its next major Mars mission. MESSENGER is scheduled to impact Mercury in late March 2015. An instrument Announcement of Opportunity (AO) for the Europa Clipper mission has been released and step 1 proposals are due by April 2015. New Horizons will fly by the Pluto/Charon system in July 2015. Juno is due to insert into Jupiter orbit in July 2016, and the InSight Mars landing will take place in September 2016. Cassini begins to de-orbit around Saturn in September 2016. A Discovery AO was released on 5 November; step 1 proposals are due in February 2015. PSD has completed a Senior Review, and all missions included in the review will continue. The R&A program has had a review (with the exception of one core program) since the R&A restructuring; the community is actively involved and is generally pleased with the process.

The Senior Review included Cassini, the Lunar Reconnaissance Orbiter (LRO), Mars Explorer Rover (MER) Opportunity, Mars Express, Mars Odyssey, the Mars Reconnaissance Orbiter (MRO) and Curiosity. Dawn, MAVEN, Juno and New Horizons were not under review as they are still in their prime missions. MESSENGER will complete its mission in the first half of 2015. The Senior Review makes its decisions based on the science value-per-dollar of, as well as the unique strengths, of extended missions (EMs). Cassini, for example, had a high probability of success based on past performance, and presented opportunities for unique future observations. For LRO's EM, some instruments will be terminated and funding will be reduced for two instruments, the Lyman Alpha Mapping Project (LAMP) and the Cosmic Ray Telescope for the Effects of Radiation (CRaTER). MER Opportunity continues its 11-year mission on the Mars surface, exploring clay-containing regions. MRO was lauded for the high number of publications it has produced. The orbiter also has operational importance for future mission site selection. Mars Express was approved for continuation of automated aspects of its High Resolution Stereo Camera (HRSC) image processing; the satellite can support MAVEN operations as well. Mars Odyssey is coming to the end of its productive science life, but is still able to contribute to an understanding of the radiation environment at Mars. MSL was approved for an EM. Although several strengths were noted for MSL, the Senior Review found issues with its current drilling proposal; now that the rover is at Mt. Sharp, PSD has asked the project to develop a new task plan for Mt. Sharp operations.

PSD has redesigned most of the R&A program, having reduced calls from 22 to 17, and aligning calls to program themes such as Emerging Worlds, Exoplanets, Laboratory Analysis of Returned Samples, etc. A two-step proposal process has been adopted; the first step is an abstract, which can be redirected to the appropriate call

if necessary, or can be judged as to how it fits science objectives. Step 2s are due about 3 months after step 1s. As an example, the EW theme received 219 proposals, for which PSD provided disposition within 23 days. Typically the proposals came into the appropriate theme. The time to notify has been consistent across the core programs. Dr. Rummel asked where technologies for developing techniques for sample return analysis go. Dr. Green reported that this is not in the core program yet.

As to the status of the radioisotope power systems (RPS) program, NASA is making modest investments in improving the fuel efficiency of its multi-mission radioisotope thermal generators (MMRTGs), with a goal of doubling the current efficiency to produce a viable flight design by late this decade. Stirling technology is being used to try to provide more power for less fuel. NASA is also studying fission systems for human exploration. The Curiosity's MMRTG continues to operate well. NASA also continues to fund Pu-238 production, with a goal of producing 1.5kg per year of plutonium oxide by 2021. Technology demonstration efforts are on schedule; the Department of Energy (DOE) is working on safety and production issues. NASA is now funding the DOE's Operations and Analysis infrastructure. PSD is holding a spare MMRTG for the Mars 2020 mission.

Dr. Green reviewed notable PSD science missions. The MAVEN orbit insertion went flawlessly. In its preliminary 35-hour orbit it was able to take a look at atomic carbon, H, and O. Data indicate that ozone at Mars is primarily destroyed by ultraviolet radiation and water vapor. Particle instruments aboard MAVEN observed a coronal mass ejection from the Sun. Comet Siding Spring, about 500 m in size, flew within 30,000 km of Mars on October 19, 2014. Many NASA assets observed the flyby. Cometary material blanketed the northern hemisphere, where Opportunity observed it as a dayside event. Data are continuing to be analyzed. It is estimated that only 3-4 Oort cloud comets per century pass through the solar system; and near Mars, every 8 million years. The comet velocity was measured at 57 km/second. All Mars assets made science observations. In late April/May 2015, the Hubble Space Telescope (HST) will be taking more images of the Pluto/Charon system, in preparation for the New Horizons fly-by. Asked if the Astrobiology Science and Technology for Exploring Planets (ASTEP) still existed, Dr. Green noted that it had been folded into the Picasso and Matisse calls.

<u>Subcommittee Discussion</u>

The subcommittee considered the topics of Mars Sample Return (MSR), the risk of back contamination, and protocols for human exploration being developed in Europe. Dr. Kminek noted that the international consortium iMars, active in the middle of the last decade, had been a good forum for identifying knowledge gaps, and for developing a priority list of concerns. ESA used the results of the forum to fill in the program elements for its Mars robotic exploration preparatory program, which had a strong focus on the flight containment system (in the sense of biological containment of the sample cache). This technology development was started in 2010; ESA built breadboards and proof of concept units, and completed its first

phase last year. The agency will continue the activity for the next two years to develop an engineering model. The roadmaps state that the systems should be brought to TRL-5 by 2016. Because of the sealing and monitoring aspects of technology development, high-fidelity, flight-representative material must be used for those functionalities. In addition, some elements of the receiving facility are now being considered, as well as building a breadboard for sample manipulation, using double-walled systems. The first step in this area began with a working meeting some months ago in Europe, which had some US participants from Goddard and JSC. The meeting participants discussed sample manipulation system capabilities, the Draft Test Protocol, MEPAG reports on sample analysis, and a life detection conference and workshop report released in 2013. This effort helped to derive engineering requirements and will help to guide further development of sample manipulation and containment technologies.

The MEPAG and international Sample Analysis Group (iSAG) reports will feed into an update of the PP DTP, which should be developed over the next couple of years to inform the engineering/manufacturing design. Dr. Lindberg asked if current efforts address "breaking the chain" of contact. Dr. Kminek replied that the containment system must reflect the environmental stress factors and still needs refinement, as it trickles down through both passive and active elements of the containment systems. Overall, "breaking the chain" is being covered by current activities, but the concepts will have to go through a review process. What is currently missing is what the NRC has repeatedly recommended, which is the definition of an oversight role, beginning with an international perspective and an interagency one, particularly with respect to responsibilities. It is time to do this. The agencies will need a core oversight element very soon.

Dr. Conley asked what was going on in parallel with the US regarding technology development for sample analysis. The Mars program used to have a set of technology investments for this, and it needs more coordination with ESA. There is programmatic funding in PSD in R&A for sample analysis, but it is not clear what is there. A trade study has been requested by the MEP for both forward and back contamination issues in sample containment. OPP is trying to improve coordination with the Mars program. Dr. Kminek pointed out that technology development activities are being funded by the ESA Mars program, not its PP arm, and felt that the best way to address some of these issues is to avoid certain substances that would introduce a source of contamination, such as adhesives for screw locks- items such as these must be addressed early to identify requirements.
Dr. Hipkin commented on a recent international discussion of sample return, which also addressed the management and responsibilities of a dedicated institute. As a result, there may be a recommendation to have more work done on the DTP sooner rather than later to help organize this effort. There has been a call for an integrated approach for both PP and science requirements (biohazard vs. science) in the same document, which may require more resources from the PP offices.

Dr. Conley addressed oversight over sample return activities, commenting that

NASA hoped to get more interagency and international coordination, as had been practiced during the Apollo era. Dr. Kminek recommended that a clear decision be made to form an oversight committee as soon as possible, followed by real activity such as establishing a charter and membership. Dr. Lindberg felt that OSTP should be coordinating this effort. Dr. Rummel noted there is a coordination process run by the White House that might be used to formulate a solution. As it takes about 10 years to plan a sample handling facility, NASA must also consider a 5-year "political bow wave" surrounding the concept of sample return. Rosetta is a case in point, having been a ten-year mission. Dr. Conley reported that the sample collection Level 1 requirements are being considered right now, therefore the international oversight committee needs to be set up now. Dr. Teplitz suggested that NASA might do well to present a potential solution to the Committee on the Peaceful Uses of Outer Space (CPUOS).

Public comment period

Teleconference participant Mr. John Cooper posed the question: who decides when the Moon becomes an object for exploitation and habitation vs. protection? Dr. Conley noted that at the moment, PP policy poses no restrictions on operations. In recognition of scientific interest, there is documentation required concerning volatiles carried by spacecraft at the Moon. Dr. Rummel explained that while the Outer Space Treaty still defines the protocols, providing guidance on both use and protection of assets at the Moon, it does not give "permission" to operate on the Moon. Dr. Lindberg noted that the question also speaks to the uncharted experiences of commercial entities in space, which will entail the increased participation of the State Department and the FAA. Mr. Cooper asked if there were any policy in place for dealing with polar ice regions on Mercury, the Moon, etc? Dr. Conley replied that policy for these bodies is recognized internationally and within NASA, and requires additional documentation, which is already in place for PP.

Europa planning status

Dr. Curt Niebur reported on the status of the Europa Clipper mission concepts, which to date have not yet been reviewed through the Agency approval process. Dr. Niebur cautioned that cost estimates and instrument costs remain notional. The mission class is not yet specified, although concepts discussed are at about $2B. NASA had requested concepts costing less than $1B, a call which received 6 proposals, but all of which were estimated at higher costs.

Europa likely has a liquid water ocean capped by a solid crust of ice; this was an unexpected finding made by the Galileo mission. Science questions to be answered by a proposed mission are: how deep and salty is the ocean; how active and how thick is the ice shell; what's in the southern polar region plumes that are evidently being vented from Europa's surface (as seen by HST spectrometer); and what's the brown stuff (dark striae on the surface)? The drive to answer these questions has guided mission concepts for 15 years.

Mission concepts have included a Europa orbiter (2001), which was eliminated due to high radiation exposure and higher costs associated with radiation-hard parts. The Jupiter Icy Moons Orbiter (JIMO; 2004) featured an increased science scope, which also greatly increased costs. The Europa Explorer and Jupiter Europa Orbiter (2007-11) mission concepts were costed at $4-5B. A Europa Orbiter (2013) bare bones mission was estimated to cost at $2B. A Europa Lander (2013) was to cost $4B for a one-month mission lifetime. Studies eventually led to reevaluation of mission concepts, based on the premise that the next objective should be an orbiter, as Galileo had already provided a fly-by. Experience at Cassini had helped to inform an alternative approach; in this case, one can take advantage of the Jupiter orbit to execute multiple fly-bys of Europa. Fly-by approaches also mitigate the severe radiation environment and reduce the need for large amounts of fuel. Multiple fly-bys can obtain global-regional coverage of Europa, and allow for a downlink to transmit a high volume of data.

The JPL Clipper concept, which was costed at about $2B in FY15 dollars, excluding the launch vehicle, can obtain about 80% of the desired science for about 50% of the cost of other concepts (as estimated by a science definition team and independent board). The lowest fly-by is 25 km above Europa's surface. Such a mission could respond to discoveries within 2 fly-bys. The Clipper would carry out 45 fly-bys over a two-year period. JPL chartered a mission concept review (MCR), which characterized mission concept as "brilliant and exquisite." Upcoming efforts include 57 dedicated HST observations to try to verify the existence of plumes. The Clipper could presumably examine these plumes. NASA plans to host a workshop with key players in the field to understand how to integrate the plumes into the mission concept if they exist. NASA will release a Stand-Alone Mission of Opportunity Notice (SALMON) 2 Program Element Appendix (PEA) in July 2015 to solicit flight instruments for an unspecified Europa mission. Selections are expected in April 2015. Dr. Lindberg asked if there were any ideas circulating about plume mechanisms on Enceladus. Dr. Niebur replied that there are various ideas, but no consensus; there seems to be agreement that the mechanism is probably different on Europa- Europa has larger ocean, is a larger body, and its ice crust is thicker. Europa seems to have more areas of hydrothermal spreading rather than subduction.

<u>Director, Mars Program Remarks</u>

Dr. Michael Meyer spoke in lieu of Dr. James Watzin, the newly selected Director of Mars program who will begin employment on 1 December. 2014 has been a very good year for Mars missions and development of upcoming missions. MAVEN is doing very well and officially entered its science campaign on 15 November. Curiosity reached Mt. Sharp in September, earlier than anticipated, and its wheel wear problems have been solved. Mars Odyssey, ISRO's MOM, ESA Mars Express, MER Opportunity and MRO continue to operate well. The ESA Trace Gas Orbiter is set to launch in 2016, on which NASA is flying an Electra communication device. The Discovery mission Insight is also scheduled to launch in 2016. In 2018, the ESA ExoMars rover will launch; NASA has an organics analyzer on board the rover.

ExoMars will be followed by the Mars 2020 rover. Dr. Lindberg asked if ISRO's MOM could provide relay for NASA. Dr. Meyer felt this would not be possible due to its positioning.

The Mars 2020 mission will conduct rigorous *in situ* science using MSL architecture, and will traverse to geologically diverse sites to search for signs of habitability; take nested measurements from regional to fine scale; enable future *in situ* resource utilization (ISRU) capabilities; and prepare for sample return. ISRU will not be a Level 1 requirement, however. The instrument suite includes Mastcam Z (an imager which incorporates a zoom capability) and a SuperCam (French laser contribution). The payload will contain a color imager, as well as Raman laser-induced breakdown (LIB) and NIR spectrometers. PIXL will provide a map of elemental composition, and Sherlock, a UV Raman spectrometer will give fluorescence and mineralogy data. MEDA is a weather station to be provided by Spain, and MOXI is the ISRU instrument, which will generate H_2O from CO_2 breakdown. RIMFAX is an instrument that will measure the subsurface up to 500 m in depth.

Mars Special Regions Update Activity

Dr. Kminek provided an update on progress on Mars Special Regions, defined largely as regions possessing high potential for harboring martian life, or regions that would support the replication of terrestrial organisms. Quantitative requirements have been put in place as a result of a major 2006 MEPAG report. Given current knowledge, special regions (SRs) are defined as areas that have sufficient water activity AND sufficiently warm temperatures to permit replication of Earth organisms. Features that have been observed on Mars that have a likely association with SRs include gullies and bright streaks associated with gullies, pasted-on terrains, subsurface below 5 m, dark streaks and other features to be determined by further investigation. A spacecraft that lands on or has access to a Mars SR will require stringent biological controls. Parameters of Mars Special Regions were examined by a report by the MEPAG SR-SAG2, completed in July 2014, and which will be published by Astrobiology (in press). The Mars Special Regions concept including the MEPAG SR-SAG2 report, will be reviewed by a joint ESF-NRC committee. This process is to be finished by June 2015, after which the report will be relayed to COSPAR for adoption by the COSPAR Bureau and Council. The output will be presented to the PPS and the European PP Working Group (PPWG). There needs to be a quicker way to use the scientific findings in implementing PP policy, as there are many assets at Mars that may change the current knowledge base, such as Phoenix data, which raised questions about survivability of microorganisms under certain conditions, and the implications raised by RSLs, which may indicate the presence of shallow water over more extensive regions on Mars. Dr. Conley agreed that there is a need for more frequent updates, based on evolving data on biological parameters for terrestrial microbes.

Asteroid Redirect Mission

Dr. Michele Gates, Program Director (PM) for ARM and Steve Stich, Crewed Mission Lead, provided an overview on the Asteroid Redirect Mission (ARM). ARM fits within NASA's phased approach to human exploration at Mars, comprised of three phases: Building Blocks to Mars, Earth Reliant, Proving Ground, and Earth Independent. ARM is the initial mission in the Proving Ground phase. ARM requires identification of a candidate asteroid target, to be identified by SMD; a redirect of a substantially-sized asteroid by solar-electric propulsion (SEP) mission to a *cis*-lunar orbit, and; exploration by crew in an Orion vehicle, launched aboard the Space Launch System (SLS), to target to obtain asteroid samples. The current objective is to conduct a human mission to an asteroid in the mid-2020s, and to demonstrate an advanced SEP system, to enable future human and robotic exploration with applications to nation's public and private sector space. Among the objectives of the ARM are enhancement of detection of near-Earth objects (NEOs), demonstration of basic planetary defense techniques that will inform impact mitigation strategies to protect Earth, and pursuit of a target of opportunity that benefits both scientific and commercial interests.

Dr. Steve Stich provided background on the development of ARM, characterized as an affordable mission that could make progress toward human exploration of Mars. ARM involves an ambitious trajectory, that includes an outbound flight time of 8 days, 9 hours; and a return flight time of 11 days, 6 hours. An asteroid would be ferried to a 71433-km distant retrograde orbit (DRO) that is regarded to be stable for 80-100 years. There are two or three launch opportunities per month. Dr. Stich reviewed integrated flight attitudes, which allow for adequate extravehicular activity (EVA) lighting and thermal conditions, and displayed accommodations for a crewed mission that is basically the same system used at the International Space Station (ISS), with the addition of pre-positioned toolboxes for EVAs and modified EVA suits and re-pressurization kits. Cabin pressures and rebreathing schemes, such as those used for HST repair missions, will also be used for ARM. Sample containment strategies will be similar to those of Apollo-era schemes, but these are still under development. A modified Advanced Crew Escape Suit (ACES) and life support systems have been tested under various conditions, and seem to provide the flexibility and mobility to carry out many of the necessary ARM tasks. These concepts can feed forward to Mars with further modifications. ARM is working with the Curation Analysis Planning Team for Extraterrestrial Materials (CAPTEM) group on sample collection and characterization. CAPTEM has provided a total of 10 recommendations relative to placement of instruments, photo-documentation of samples, etc. Dr. Jon Miller expressed concern about crew exposure to solar radiation during a 30-day mission. Dr. Stich noted that the program is working with radiation experts, who agree that exposure will have to be monitored, but that the mission duration is not of concern. The CME case is the highest risk item. Orion has some shielding capability, depending on the duration of the mission and number of crew members; the shielding capability is certainly better than that of the Apollo Lunar Expedition Module (LEM).

Asked if a budget and schedule comparison had been performed as to a crewed vs. robotic mission, Dr. Stich reported that the comparison has not been done, adding that ARM's main purpose is human exploration and the testing of Orion's capability, learning how to do complex trajectory missions, and ultimately moving out to the higher risk of a human mission to Mars. Mr. Bob Gershman pointed out that NASA is in fact sending a robotic mission to an asteroid ; i.e. OSIRIS-REx. Dr. Gates felt that the comparison was not valid. Dr. Doran asked if the planetary defense objective was more primary to ARM. Dr. Gates replied that planetary defense has already been raised to the level of a primary objective, whereas it had previously been a secondary objective. Dr. Karen Bishop of Safety and Mission Assurance asked if loss-of-crew requirement numbers had been tabulated. Dr. Stich responded that ARM is already looking at big drivers for safety such as major system failures, but has not gotten to those numbers yet. The ARM could provide the benefits of robotic mission capabilities to future missions to Mars by exploring split mission concepts, prepositioning habitats, etc. The combination of ARM and ISS can be used to provide the first steps to Mars such as heavy lift, upper stage development and deep space habitats. Dr. Lindberg felt that long-duration radiation protection concepts were lacking.

Mr. Gershman addressed the PP considerations of ARM. NRC concluded in 1998 that asteroid sample return would not require the special containment conditions that have been promulgated in 8020.12D. However, ARM presents unique considerations for PP. Its final target selection will take place shortly before launch, but NASA can't wait for final target selection to design for PP. The mission capture option may also influence PP. Currently, ARM is considering returning an entire 10-meter asteroid or returning a boulder from a larger near-Earth Asteroid (NEA) (2-3 m object). ARM's earliest launch date is mid-2019, thus the target could be selected as late as 2018. NASA anticipates a request for final characterization in mid-2018. The earliest return of an object to DRO (crewed mission) would take place in 2023-24. ARM will seek some form of provisional categorization of PP by December 2015.

Mr. Gershman reviewed radiation histories of asteroid materials, which have undergone billions of years of exposure from the internal decay of U-238 and other active radionuclides. Also, most ARM targets have been exposed to galactic cosmic rays (GCRs) for tens of millions of years giving dosages far exceeding the dosage used for the most extreme sterilization procedures on Earth. Possible exceptions regarding GCRs are asteroids linked to CM and CI meteorites (shorter exposures, hundreds of thousands of years); it is of note that Bennu and 1999 JU3 have some similarities to CM- and CI-class carbonaceous chondrites. Thus far, ARM is basing its asteroid radiation exposure estimates on the "Ben Clark" chart. Additional data are provided by recent findings that material from the same asteroid sources as ARM targets have been striking Earth for billions of years, implying that any dangerous material on these bodies has already reached and contaminated Earth. Dr. Miller questioned the purpose of sampling an asteroid if everything on it is presumed dead. Dr. Conley noted that the amount of radiation needed to kill a large organism

is much less than that needed to alter smaller prebiotic molecules, the latter of which would be a valuable discovery.

Final PP categorization will be requested when the final target is selected. Dr. Lindberg commented that the provisional characterization will drive the requirements for the mission, and that ARM must keep this in mind.

Public comment period
No comments were noted.

Subcommittee discussion
Dr. Lindberg addressed the preliminary results from MSL's SAM and DAN instruments, and the questions they raise with respect to special regions on Mars, and asked when PPS could expect to see categorization of the Mars 2020 mission, and whether such categorization was currently relevant to MSL (potential re-categorization during the course of surface operations; i.e. encountering SRs unexpectedly). Dr. Conley replied that a mechanism is currently in place for relay of this information from MEP to the PPO. Dr. Kminek remarked that one must keep in mind that PP would be responding to pre-public information in the event of a sudden need for re-categorization. Dr. Gerhard Schwehm commented that mission participants should be responsible for establishing an alert system. Dr. Conley sought specifics to provide to each project, such as specific triggers that characterize special regions and how a mission might go about reporting these. Dr. Lindberg noted that the discussion exemplifies the conflict between the science requirements and PP objectives, and asked for clarification of the ongoing role of PPO once a mission is on the surface. Dr. Conley reported that PPO is not routinely involved in oversight of the science, partly because the office is so small. More formal interaction would be beneficial, and more frequent updates from MSL instruments could also be helpful to PPO. The roles and responsibilities of PPO and PPS, however, extend to assuring that processes exist to enable the review of potentially concerning scientific data. Dr. Schwehm asked if the NASA PPO had the authority to stop or delay mission operations until an issue is resolved, and whether the mission was required to provide proof that a site to be visited is not in fact a special region. Dr. Hipkin commented that there were two challenges for monitoring for the existence of special regions: modifying orbits to allow for obtaining images; and determining how many Mars years are needed to answer questions about special regions. Dr. Doran noted that in science operations at Antarctica, research teams are forbidden to drill in wet areas; burden is on the research team to prove that an area is dry. Dr. Kminek added that for instruments, there is a time allocation for pure science use and Agency-level use, for priority targets. Appropriate PP requirements can't be established in the absence of data, therefore an approach that integrates both PP concerns and scientific validity of measurements would be most helpful. Dr. Miller suggested that a reasonable model exists in human subject research, wherein researchers are obligated to report adverse reactions, etc. within 24 hours. PP regulations could be constructed in a similar fashion.

Dr. Hipkin felt that PP is solidly aligned with science in determining the significance of RSLs, based on HiRise experience. Regarding the DAN and SAM data, it is important to distinguish whether they indicate the presence of ice or bound water. Dr. Meyer addressed questions from PPS regarding the MSL Curiosity rover and the collection of new data, and HiRise data that is collected concurrently, which may indicate that Curiosity might be able to access a special region: who looks at the data to gain that understanding, and what is the process by which the science team shares data with PPO on potential special region indicators? Dr. Meyer felt the current MSL/PP interaction is pretty solid, and will continue as part of Mars 2020 planning, and thus will act as a normal conduit for information. The MEP has been relaying SAM information to the Organic Contamination Panel (OCP), for instance. The project understands that the rover is not to enter special regions. Science discussions tend to be very wide-ranging, although it takes some time to acquire enough data to make a definitive statement on PP. It is also not unusual for Headquarters to request certain operations to acquire data. Dr. Meyer felt there were enough PP staff to be aware of pressing issues. Dr. Conley requested a more formal recognition from the science team that PP is part of the process. Dr. Meyer felt that because of the large size of the science team, rules have been a bit more restrictive due to publication embargoes and the peer review process. The mission wants to encourage free scientific discussion without being paranoid about data in process. The atmosphere has in fact become less restrictive following the first wave of publications. Dr. Meyer invited Dr. Conley to join the science team, and sign on to the rules, i.e. all the mission information is available internally. Dr. Kminek agreed that while it was important to preserve open discussion on mission science teams, it might be more useful to have more sensitivity on the science side to interface with the PP element. Public subcommittees might not be the best forum, as they can't deal with proprietary information. In addition, more than one expert in the field will be required to evaluate the issue at hand. Dr. Lindberg noted that a more appropriate role for the subcommittee is to see to it that the processes are in place for communication between the missions and PP to occur.

Dr. Meyer relayed that the SAM team has been struggling with the source of organic carbon for nearly a year, and that he did not want to short-circuit the process of trying to figure out what the data mean. Dr. Lindberg suggested that a private discussion be convened in the matter. Dr. Meyer acknowledged the RSL issue and reported that the team is watching them. Dr. Hipkin commented that the observation approach is difficult due to illumination issues, etc., and it will be hard to get definitive evidence. Dr. Kminek felt it would be worth discussing several ways to assess the possibilities, based on risk assessment; the mission could carry out additional risk assessment activities to see if Curiosity can perform useful maneuvers. This should be done now to so that the data is available should the rover approach an RSL within a year's time. Dr. Miller asked if there was an understanding in place that the MSL team that must stand down in the event of encountering a special region. Dr. Meyer replied that while there is a mechanism leading up to launch whereby PP ensures that requirements must be met, if the classification of the environment changes, there is no formal process for dealing with it, as yet.

November 18, 2014

Opening Remarks

Dr. Lindberg reviewed topics raised on the previous day, including international/interagency collaboration; re-categorization of a mission due to science discovery; addressing in a preliminary way the categorization of Mars 2020; commercial actors in the space industry; and the challenge of meeting Outer Space Treaty obligations.

Mars 2020 Project Mars Sample Return Contamination Requirements

Dr. Matt Wallace briefed PPS on the general features of the Mars 2020 mission, currently scheduled for launch in July/August 2020. The mission is based on high heritage from MSL and entails a 7.5 month cruise time to Mars, the re-use of the successful SkyCrane Entry Descent and Landing (EDL) system, and the placement of a 950-kg rover on the martian surface for one Mars year (2 Earth years). The Mars 2020 rover will have a slightly reduced landing ellipse, a 20-km traverse capability, and a payload that includes a returnable cache of samples. Dr. Wallace reviewed the chronology of the mission since MCR. The instrument selection was made in July, followed by a sampling/caching review in October. During the next year or so, there will be complete instrument accommodation and payload system reviews, and Preliminary Design Reviews (PDRs) in late Spring/early Summer for EDL and operations. A second landing site workshop will be held in August 2015 in California. The Key Decision Point-C milestone (KDP-C) will be held in late 2015.

The scientific objectives of Mars include an investigation of the geologic history at Mars, *in situ* astrobiology (looking for habitable ancient environments and biosignatures), and collection of rigorously documented and selected samples for possible return to Earth. Additional objectives are related to the future exploration of Mars, including ISRU demonstration (creating oxygen from the largely carbon dioxide atmosphere). The rover will carry a 7-instrument payload, 2 of which are sponsored by SMD/HEO. Three of the 7 instruments represent substantial international contributions, and 2 instruments are being fully contributed by Spain and Norway. Many of the instruments have lineage from MER and MSL; the interfaces are well understood, but the instruments have substantially enhanced capabilities as well. The MastCam principal investigator (PI) is Jim Bell; and SuperCam (Roger Wiens) has major French and Spanish involvement. Sherlock, a deep UV Raman instrument with exceptional spatial resolution, is being developed by Luther Beegle at JPL. PIXL is an instrument for fine scale chemistry, contributed by Abigail Allwood at JPL; RIMFAX is a radar sounder subsurface experiment contributed by Norway PI Svein-Erik Hamran. MEDA is the mineralogical monitoring instrument, contributed by Jose Rodriguez Manfredi of Spain; and MOXIE converts CO_2 to O_2 as possible future resource (PI Michael Hecht; MIT with JPL build).

Dr. Wallace reviewed candidate landing sites. The mission has considered more than 40 candidate sites, many clustered in the NE Syrtis Major area, and is now busy considering engineering requirements, as well as a hazard avoidance capability to enable traverse to

geologically heterogeneous sites (i.e. terrain relative navigation). Site selection continues, with a final decision expected by July 2019. The descent stage has many components that are re-builds, therefore the mission has the ability to complete the building of heritage systems early in the development schedule.

Dr. Mark Underwood has recently been hired as a PP Assurance Lead; he is a very senior manager with much technology development experience He does not report up through SMA- he will be a direct interface with PPO and Headquarters. Dr. Lindberg stated that he was very pleased with the organizational chart, and was glad to see PP included in the system on the same level as other mission assurance functions. Dr. Wallace felt there was more work to do in order to help Mars 2020 to interact more in alignment with Agency lines of authority.

Dr. Wallace reviewed four Level 1 (L1) requirements that deal specifically with organic contamination and PP. Mars 2020 L1 requirements #15-18 deal with the anticipated PP categorization of IVb implemented at the subsystem level; this defines organic sample return contamination levels to specific (ppb) levels, and calls for identification, quantification and documentation of pre-launch terrestrial contamination sources, as well as mechanisms to support the characterization of round-trip terrestrial contamination. In addition, L1 requirements state that the designing, cleaning, verification of the sampling chain be arranged such that each returned sample set has less than one viable organism. MSL, by comparison, did not have specific L1 requirements related to PP. Dr. Lindberg noted that it would be useful to describe this improved process to the community, inasmuch as it simplifies implementation of PP.

The project is continuing through its key milestones, heritage hardware build, landing site work, sampling system architecture, and payload selection and accommodation, and will be able to devote much intellectual energy into newer aspects of the system. Confirmation activities are targeted for late Fall/early Winter 2015/16. Dr. Rummel asked when the method for caching and retrieval would be determined. Dr. Wallace replied that the project has been doing a lot of hardware building, designing robot arms, etc., has narrowed down the trade space, and is now moving to preliminary design- there is very little surface are that comes in contact with the sample. The rotary percussive drill contains a hollow bit; the rock is drilled, captured in a tube and sealed. The tubes and bits are easy to clean, with very little exposure time on the surface. For retrieval, a fetch rover will pick up the sample from the ground or the rover, after which the sample will be returned to an ascent vehicle, captured by orbiter and returned to Earth. Dr. Rummel asked how the rover would be kept out of contact with the return canister. Dr. Wallace acknowledged that the sample must be protected and tightly sealed; this recognition is part of the engineering system planning. PPS discussed introducing probability and confidence levels to verification numbers for contaminants. Dr. Kminek noted that one can measure pre-sterilization and then apply a validated process; measuring contamination per sample mass is relatively straightforward, using blanks. For biological contamination, however, the methods are more tricky. Dr. Rummel suggested using figures of merit. Dr. Wallace commented that the project understands the problem, and that cleaning components to sterile levels is not an issue. The issue is carrying out the

transport analysis and understanding it. He agreed with Dr. Rummel on the value of using figures of merit.

Joint PPS/PPWG Meeting

The PPS briefly discussed holding a joint NASA PPS/ESA PPWG meeting in Europe some time in 2015. While the intent had been to meet every two years, NASA travel issues obstructed the last scheduled biannual meeting. The Agency recognizes the value of such a meeting. Dr. Kminek felt the first meeting had been very valuable, especially for the exchange information on what is critical to do next in terms of technology development in PP. These issues require face-to-face discussions. ESA and NASA can share R&D activities, as well, as both agencies can contribute funds. Dr. Lindberg requested that Kminek arrange ESA host a meeting in Europe, while PPS must find a way to attend. Dr. Kminek suggested Torino, Italy, or the Max Planck Institute in Goettingen, Germany, as possible sites, as both locations are hosting preparatory work for future Mars missions.

HEOMD/Evolvable Mars

Dr. Jason Crusan presented an update on the Evolvable Mars Campaign, the latest approach to Mars missions. Unlike the mission-centric philosophy of Apollo, human space flight planning for Mars as an ultimate destination includes ISS expeditions and research, without a defined end. The goal is to extend the human reach into space for increasingly extended periods of time. A three-phase approach to the goal is being carried out at HEOMD: these phases are Earth Reliant, Proving Ground, and Earth Independent. The campaign is currently in the Earth Reliant phase. Earth Independent will represent human presence at Mars. HEOMD will develop technologies during the Proving Ground period to create tools and technology to for the Earth Independent phase. The Mars goal is written into the current NASA Strategic Plan (Objective 1.1), which states that NASA will expand human presence into the Solar System and to the surface of Mars to advance exploration, science, innovation, benefits to humanity and international collaboration. During the Earth Reliant phase, typical mission durations are 6 to 12 months, with hours to return to Earth. The Proving Ground phase mission durations will be 1 to 12 months, with days to return to Earth. In the Earth Independent phase, there will be 2- to 3-year missions, with months to return to Earth.

The Evolvable Mars Campaign (EMC) involves SEP, which will be used to help pre-stage cargo, and pre-deploy surface habitation and ISRU equipment. ISRU has always been part of Mars planning, but HEOMD has been reevaluating it to perhaps play a role beyond providing oxidizers for propellants. Key objectives in the Earth Reliant phase include developing and validating technologies on ISS as much as possible, moving to more autonomous configurations, next-generation space suits, communications with increased delay, etc. Long-duration health evaluations will also be carried out, and NASA continues to move to acquire commercial crew transportation vehicles for routine transport to low-Earth orbit (LEO).

Proving Ground near-term objectives include the use of the Space Launch System (SLS) and the deployment of Orion in deep space, SEP, long duration flights, deep space

habitation systems, mitigation techniques for crew health and performance in deep space environment, ISRU, extravehicular activities (EVAs) in deep space, human and robotic missions, as well as capability pathfinder and strategic knowledge gap (SKG) missions. EMC still faces significant issues with radiation exposure, particularly GCR and solar flares. Curiosity data indicate that exposure translates to an increased cancer risk at the 5% level (as opposed to the accepted level of 3%). Dr. Miller commented that CMEs are still a major hurdle according to recent NRC assessments; a CME-associated crew death could set the program back 50 years. Dr. Crusan reported that the radiation status will be discussed at an HEO NAC meeting in December. Dr. Hipkin asked if EMC was considering closed-loop life support systems for deep space habitats. Dr. Crusan replied that the program was using about an 85% closed loop on water systems, and is retrofitting ISS with urine processor assemblies. All systems are chemical thus far, not microbial or plant-based. Dr. Green commented that NASA is also planning for order-of-magnitude improvements in high-bandwidth optical communications systems.

Guiding principles for EMC include the development of sustainable exploration strategies that are implementable in the near-term and within budget; exploration that enables both science and validation and verification methods; use of near-term mission opportunities to sustain cadence (yearly human flights); application of high Technology Readiness level (TRL) technologies for near-term missions while developing capabilities to address future missions; providing opportunities for US commercial business; development of multi-use evolvable space infrastructure with an eventual goal of building deep space habitats; and substantial international and commercial participation, leveraging ISS and other partnerships.

Mars Capability Categories will be elucidated in technology roadmaps that will be released in Spring 2015. There are 14 system maturation teams that will evaluate technical performance levels in order to execute a suite of missions, and prioritize next steps. In response to a question about suit performances in atmospheric conditions, Dr. Crusan reported that suits meet standards for rapid EVA conditions, as well as for ISS levels, in-transit and surface protocols. Dr. Lindberg asked where PP requirements are infused in this architecture. Dr. Crusan replied that for the most part, PP is cross-cutting, with separate activities that deal with microbial monitoring and detection. Dr. Allen noted that HEO has established a program to measure microbial loads at ISS. Dr. Crusan added that under the current architecture, suits stay out of the vehicle. Dr. Johnson noted that the Office of the Chief Technologist (OCT) roadmap is also informed by these PP standards, which will be integrated into technology development. Dr. Doran commented that working in space and on the surface are very different with respect to PP. Dr. Crusan noted that there was a need to minimize the number of new and unique investments, and that it was good to have all mitigation strategies in place while testing and utilizing.

The guiding philosophy for the EMC is to develop different options to provide a range of capabilities that can be used as guidelines to journey toward Mars in the mid-2030s. PP topic areas include sample handling (Biohazard Safety Level requirements), contamination control (instrument specifications), microbial transport mechanisms and venting, and crew safety (protocols for quarantine, operations, surface element design).

Dr. Doran commented that the lack of fully closed systems is going to be a big deal for PP.

A traverse to Mars with a four-person crew is envisioned as a split mission with SEP and chemical propulsion. Components can be sent ahead of crew via SEP in a transit period of 2-3 years, pre-emplacing habitats and ISRU systems. An aggregate habitation system can be built in a deep retrograde orbit (DRO), after which crew is launched via combination chemical/SEP systems. HEO is doing long-term tracking of nuclear/thermal propulsion for crew transit as well. Thus far the project has received expert input to integrate into its analyses for Mars sample acquisition and handling; sterilization needs; reducing the potential for contamination of Mars; horizontal mobility; dust mitigation; and interaction of the Mars crew with surface. Dr. Green added that the Mars 2020 mission would be the first step for sample return; the architecture in progress for 2020 includes concepts for human-assisted or robotic sample transfer to a Mars Ascent Vehicle (MAV) in the simplest possible way. In the near-term planning for Mars 2020, a workshop will be held for site selection (including sites for possible human exploration), and orbiters will be tasked to acquire hi-resolution data on the sites to determine the potential overlap between 2020 sample collection and human sites. Dr. Doran noted that the NRC *Safe on Mars* report supports a robotic sample return before human presence on Mars, thus it is important and timely to identify potential human sites as supported by sample return. Dr. Johnson added that there is much literature that supports "characterization" of landing sites prior to human visitation, although there is no prohibition against human presence in the absence of prior sampling.

State Department- Interagency Coordination

Ms. Amber Charlesworth, representative of State Department, gave PPS a briefing on space activities being planned by commercial entities such as Bigelow Aerospace and ViviSat, both of which have approached the government to seek guidance on abiding by Article 6 of the Outer Space Treaty for authorization and continuing supervision. An FAA licensing regime is required for launch and re-entry, an FCC license is required for broadcast, and the National Atmospheric and Oceanic Administration (NOAA) provides remote sensing. The current licensing structure needs to be evolved to ensure that these commercial entities meet international regulations. Article 9 PP elements must also be considered and are increasingly being discussed at the State Department. Ms. Charlesworth noted that her boss Ken Hodgkins had been reaching out to the three regulatory agencies to enable these commercial entities to comply with Article 9. Dr. Lindberg noted that one possible way to insert PP requirements is through the existing FAA relationship, as they regulate exit from Earth and re-assert their authority at re-entry. It may be expedient to require compliance with other aspects of the Outer Space Treaty as elements to satisfy conditions for FAA licensing. Ms. Robin Frank of NASA's Office of General Counsel reported that the Agency has engaged with FAA, which does not believe its current authority is sufficient, thus new legislation is under consideration. Dr. Rummel noted that the U.S. obligation under the Outer Space Treaty is to prevent harm to bodies in the Solar System, and pointed out that the State Department has the authority to instruct FAA to take on the requisite authority. Ms. Charlesworth reported that the State Department recognizes that the competency to judge PP compliance lies in

NASA even though it is not a regulatory agency, and that State is very interested in NASA's view.

Discussion

The subcommittee discussed ways in which to address PP circumstances that change during a mission. Dr. Kminek explained ESA's approach; e.g., if anything changes after launch, there must be a review to evaluate consequences and mitigate risks if necessary. In an ongoing mission, the reaction would have to be within days or weeks, during which time the mission in question would invite ESA experts as well as external experts to evaluate the situation. Dr. Lindberg asked if explicit instructions existed for potential categorization changes, noting that the MSL change had been initiated because the mission became non-compliant with Category IVc requirements; the letter of recategorization contained explicit instructions to avoid touching special regions such as an RSL, and to communicate the situation. There still needs to be a threshold measurement for definition of recategorization. While the DAN and SAM instruments can be used to measure hydration states for MSL, the data must be translated into meaningful information. There is currently no requirement to prove that one is not in a special region at every step of the way. Dr. Kminek suggested a proper review of the data, in the model of a mishap investigation board for quick response. Dr. Lindberg noted that PPS can call for a review under Federal Advisory Committee Act (FACA) rules. Dr. Rummel added that the PPO can also call for a review.

Dr. Doran commented that hydration states change quickly, perhaps too quickly for an effective intervention. Dr. Rummel countered that RSLs are defined by imagery from orbiters; when MERs were going into craters, there was always a review beforehand. It shouldn't be difficult to have a review, and have the Associate Administrator (AA) direct the project away from the suspect region. Dr. Miller noted that human research protocols now require investigators to participate in specific tutorials to join in scientific projects; a parallel process may be useful for training in PP compliance. Dr. Lindberg felt there may be value in sensitizing the science team more specifically to PP requirements (e.g., remind them to be aware of hydration states), joined with a communication from the PPO to the AA to remind the science team of their obligations. Dr. Hipkin was concerned that results may not be useful operationally, as there is already difficulty in using relevant data decisionally; the DAN results, for instance, were much lower than those indicated by orbital assets. It may be more useful to perform repeat imaging as a target of concern is approached. Dr. Doran suggested an instrument proposal for sensing special regions. Dr. Lindberg felt a useful approach might be to instruct the Program such that if an RSL is confirmed, have the PPO notified. Dr. Hipkin recommended calling an open workshop to look at the publicly available HiRise imagery to assess the dark streaks. Dr. Conley suggested encouraging better communication between the science team and the PPO. Dr. Lindberg reminded PPS about ground rules from AA, and sensitivity training. Dr. Allen suggested that NASA emulate ESA rules for the different levels of training required for flight hardware builders; i.e. regular certification training in PP. Dr. Kminek described the MEPAG SR-SAG2 proposed classification scheme for dealing with special regions on Mars: fully confirmed (repeated images); partially confirmed (changes and incremental growth but not both); suspect (suggestive morphology, not enough images to

confirm growth or seasonal dependence). Dr. Rummel noted that MSL itself is able to sense a special region, if there were enough water in the soil.

Public comment
No comments were noted.

Discussion/Wrap-Up
PPS discussed potential findings. It was generally considered that a finding on commercial actors in space would be premature at present. Dr. Rummel reported that he had been advising the MarsOne project on PP, noting that their colonization plan puts them out of the range for most special regions. In addition, Netherlands has the same obligations under the Outer Space Treaty as any other treaty signatory. Karen Bishop reported having been at a harmonization meeting with Bigelow, which has been working with the FAA in defining astronaut requirements; the FAA is using human-rated guidelines derived from NASA. Dr. Conley cited a prior recommendation from a May 2011 PPS meeting, which found that the FAA/DOT license applications include an assessment by SMD to ensure PP protocols are followed, when dealing with non-governmental space companies. The prior recommendation was consistent with the PPS discussion.

Dr. Green joined the meeting for discussion. Dr. Lindberg reported being very pleased with the progress PPS had seen in the implementation of the MSL Lessons Learned study, particularly in the hiring of the PP Mission Assurance Lead. This hiring was an implicit indication to the entire engineering team of the importance of PP. Dr. Lindberg raised the issue of establishing an independent reporting line analogous to the Agency's Safety and Mission Assurance organizational structure. Dr. Green felt that any potential change in the reporting structure would depend on how the project moves to satisfy Level 1 requirements, and recommended that PPS wait until the process unfolds over the next year. The ability to get the PP L1 requirements to the current level was a nontrivial effort, requiring much hard work. The next step is to get to the derived requirements; there is much more work to do. Dr. Lindberg commented that getting the PP criteria into the Level 1 requirements is a tremendous step forward, and asked how PSD would regard the customary PP categorization letter, moving forward. Dr. Green preferred that the project have one interface, as the project obtains the Level 1 requirements from the Director level, while recognizing that the Agency is at a stage where PP is forging new ground in the Mars 2020 mission. If there is some clarification that needs to be issued to the project that will be in the form of a letter from PPO, Dr. Green preferred that the PP letter go through his office. Dr. Rummel asked why Dr. Green would want the responsibility and how it would be implemented. Dr. Green felt that the project is looking for one voice at Headquarters that provides the Level 1 requirements, and any reporting through the Director level is also channeled to the SMD AA level. In the future, they will need a reporting chain. Dr. Rummel noted that it would be easy to stop any sample return based on detection of Mars life; the duality of reporting is problematic. Dr. Green believed that the Mars 2020 mission could work well with the PPO, clarify what's in 8120, and

provide the requirements. Dr. Conley noted that the proposal from Dr. Green was in direct violation of approved processes in NPR 8020.7

Dr. Lindberg felt there was the potential for a conflict of interest between mission objectives and PP, and OSMA; at some level there need to be independent bodies guarding those separate gates. The question is whether the Division Director or the SMD AA is the point at where those objectives are harmonized or competing. At what point up the chain do you harmonize? Dr. Lindberg suggested the structure require independent verification. Dr. Green pointed out that the project must address requirements in a way that is consistent with NASA management; PP can't bring in requirements late in the game. The hope is that the PP requirements integration gets ingrained enough so that the directions stand on their own. Dr. Rummel noted that all PP requirements for future sample return must be implemented from the beginning. Engineers don't have enough of an appreciation of the microbial world to make a decision to enter a special region on their own. A categorization letter can better inform those decisions.

Dr. Lindberg saw three points of interaction between PP and the project- the letter, review and concurrence with derived requirements, and then compliance with requirements. He saw no problem with the categorization letter going through the Division Director level, as it still allows the independence of the PPO to be maintained through derivation of requirements, and compliance with requirements. The letter is to allow both project and program to resolve details in implementation, and the project is responsible for implementing details. Dr. Lindberg paraphrased the discussion by stating that there is a general sense in PPS that for Mars 2020, the practice currently documented will continue (letter going straight to the project); but that the incorporation of Level 1 requirements into the systems engineering pipeline, as recommended by MSL Lessons Learned, is better than conveying requirements by letter.

Summary of observations

- In light of increased commercial and nongovernmental interest in missions that have PP consequences, PPS notes and reiterates its 2011 recommendation on this subject.

- PPS is pleased by the Mars 2020 mission structure that has been put into place in response to the MSL Lessons Learned study, and encourages further progress in this direction.

- PPS notes that PP concerns continue for the life of a mission, and final resolution of PP concerns doesn't end with requirements compliance and launch. Ongoing MSL surface operations must continue to comply with PP requirements that were articulated in the PP Letter of 2011. PPS encourages the PPO to communicate with the PSD Division Director, and through him with the project, to strengthen communications between the MSL science team and the PPO.

- The PPS would like to interact with the PPO for a strategy for approaching candidate recurring slope lineae before the mission actually does so.

PPS will continue to seek opportunities to hold a joint meeting with its European counterpart in May 2015; Drs. Allen and Conley were to take actions on moving plans forward. Items for the joint meeting agenda will include the articulation of a rationale based on the ongoing joint oversight activity of the ESF and NRC re: the Mars One proposal. Of general note, the PPS reminded the membership of the March 24-26 2015 workshop on PP SKGs for Human Extraterrestrial Missions. Dr. Kminek commented that it would be useful to have a briefing at the planned joint session on details of the Apollo ICBC in terms of oversight of contamination issues, such as the charter of the committee, and membership. Dr. Rummel noted that the ICBC lacked clout, and had been overridden by a single person. Dr. Kminek observed that the Apollo incident spoke to Lessons Learned issues, and would provide a foundation for discussion.

Dr. Lindberg adjourned the meeting at 2:48 pm.

Appendix A
Attendees

Planetary Protection Subcommittee Members
Robert Lindberg, University of Virginia, *Vice Chair PPS*
Colleen Cavanaugh, Harvard University
Catharine Conley, *Planetary Protection Officer*, NASA HQ
Peter Doran, University of Illinois, Chicago
Victoria Hipkin, Canadian Space Agency
Gerhard Kminek, European Space Agency
Jon Miller, University of Michigan
John Rummel, East Carolina University
Gerhard Schwehm, European Space Agency
Vigdor Teplitz, Department of State
Gale Allen, *Executive Secretary PPS*, NASA HQ

NASA Attendees
Jason Crusan, NASA HEOMD
James Green, NASA HQ
Karen Fisher, OSMA, NASA HQ
Bob Gershman, NASA JPL
James Johnson, NASA JSC
Michael Meyer, NASA PSD
Curt Niebur, NASA HQ
Betsy Pugel, NASA GSFC
Mitch Schulte, NASA HQ
Russell Stoewe, NASA HQ

Non-NASA Attendees
Amy Reis, Zantech IT
Karen Shelton-Muir, FAA
Perry Stabekis, Consultant
Joan Zimmermann, Zantech IT
Amy Zukosky, Lockheed Martin

Appendix B
Committee Membership

Eugene H. Levy (Chair)
Provost/Professor of Physics and Astronomy
Rice University

Catharine Conley, Planetary Protection Officer
Planetary Sciences Division
Science Mission Directorate
NASA Headquarters

Gale Allen, Executive Secretary
Deputy Chief Scientist
NASA Headquarters

Penny Boston
Department of Earth and Environmental Science
New Mexico Tech

Colleen Cavanaugh
Biological Laboratories
Harvard University

Peter Doran
Associate Professor, Earth and Environmental Sciences
University of Illinois at Chicago

Joanne Irene Gabrynowicz
University of Mississippi School of Law

Robert Lindberg
Research Professor
University of Virginia

Jon D. Miller
Joseph A. Hannah Professor of Integrative Studies
Michigan State University

John D. Rummel
Department of Biology

East Carolina University

Agency Representatives:

Kelvin Coleman
Federal Aviation Administration
Washington, D.C.

Dale Griffin
Environmental/Public Health Microbiologist
United States Geological Survey

Victoria Hipkin
Program Scientist, Planetary Exploration
Canadian Space Agency

Gerhard Kminek
European Space Agency

Gerhard H. Schwehm, SCI-OS
Head of Solar System Science Operations Division
ESAC

Vigdor Teplitz
Department of State
Washington, D.C.

Michel Viso
Astro/Exobiologie
Astrobiology
Vétérinaire/DVM
CNES/DSP/EU

Subcommittee Administrative Support:
Ms. Ann Delo
Administration Officer
NASA Headquarters

Appendix C
Presentations

1. COSPAR Report; *Gerhard Kminek*
2. Planetary Protection Status at NASA, Overview and Status; *Catharine Conley*
3. Planetary Science Division Status Report; *James Green*
4. Europa Mission Status; *Curt Niebur*
5. Director, Mars Program Remarks; *Michael Meyer for James Watzin*
6. Mars Special Regions Activity Update; *Gerhard Kminek*
7. Asteroid Redirect Mission; Michelle Gates; *Bob Gershman*
8. Mars 2020 Project; *Matt Wallace*
9. Human Exploration and Operations Mission Directorate Evolvable Mars Campaign; *Jason Crusan*