NASA ADVISORY COUNCIL

Planetary Protection Subcommittee

December 19-20, 2012

NASA Headquarters
Washington, D.C.

MEETING MINUTES

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Eugene Levy, Chair

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Amy Kaminski, Executive Secretary

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December 19, 2012

Welcome and Introduction
Executive Secretary Amy Kaminski, Senior Policy Advisor in the Office of the Chief Scientist, welcomed members and made some administrative announcements. She reminded members of Federal Advisory Committee Act (FACA) rules and potential conflicts of interest. Members of the Planetary Protection Subcommittee (PPS) introduced themselves.

Words from the Chair
Dr. Eugene Levy, Chair of the PPS, recounted the progress of the most recent PPS recommendation, which was to establish the appropriate documentation for bringing planetary protection considerations to bear onto NASA's human space exploration program. The NASA Advisory Council (NAC), which initially declined to approve this recommendation, has reversed its position after receiving an explanatory white paper from the PPS. Looking ahead, Dr. Levy noted that PPS must continue its ongoing review of planetary protection activities in a responsive mode, as well as to raise its concerns about resources for planetary protection-related technology development.

Planetary Science Division
Dr. James Green, Director of the Planetary Science Division (PSD) of the Science Mission Directorate (SMD), presented a status report for the division. He reported that Mr. Douglas McCuistion, Director of the Mars Exploration Program (MEP), would be retiring at the end of 2012, leaving Dr. Green as acting head of MEP in the interim. Major recent events were recounted: the successful launch of the Organism/Organic Exposure to Orbital Stresses (O/OREOS) mission, the transfer of the Lunar Reconnaissance Orbiter (LRO) mission into PSD through its extended mission (EM), encounters with comets Hartley-2 and Tempel-1, and the release of the Planetary Decadal Survey. The MESSENGER spacecraft was inserted into its orbit around Mercury, and the new Discovery program mission, Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight), was selected. The Dawn spacecraft departed its orbit around the asteroid Vesta and is now on its way to Ceres. PSD successfully launched the Juno mission to Jupiter. The Grail A and B (Ebb and Flow) lunar spacecrafts impacted the Moon on 17 December, successfully concluding their mission. Science analysis of the results will continue through the Research and Analysis (R&A) program.

The Mars Science Laboratory (Curiosity) landing received international attention and widespread coverage in the social media. Upcoming PSD launches include the Lunar Atmosphere and Dust Environment Explorer (LADEE), which will measure lofted dust at the Moon in and around the terminator, and determine the composition of the lunar exosphere, is scheduled to launch in August 2013 from the NASA Wallops Island facility in Virginia. LADEE will provide data at a rate of 670 Mb/second. All instruments have been delivered for this mission, and most subsystems have undergone testing. Laser communications will be received at ground stations via the Deep Space Network (DSN). LADEE will mark the first time for the Wallops facility in launching a mission to the Moon, and the first time NASA will be launching on a spacecraft on a Minotaur 5 rocket (Peacekeeper family).

The Discovery-class mission InSight was selected to perform an interior investigation of seismic activity at Mars, based on the solar-powered Phoenix lander heritage. InSight will land at an equatorial site that is yet to be determined and employ a ground-penetrating mole to take measurements within the subsurface of Mars. Within the New Frontiers (NF) $1B-class missions, New Horizons is currently en route to Pluto and the Kuiper Belt for a 2015 arrival, and Juno will arrive at Jupiter in 2016. OSIRIS-Rex, launching in September 2016, is currently in phase B and preparing for confirmation in the calendar year (CY) 2013. It is designed to obtain at least 60 g of pristine sample from the asteroid RQ 36, linger at the asteroid for 505 days, and characterize the asteroid's mass properties as well as the Yarkofsky effect. RQ36 is a potentially hazardous object. The mission is scheduled to return a sample to Earth in 2023 using a Stardust-style capsule. The next NF Announcement of Opportunity (AO) is planned for 2015/16, following the recommendations of the Decadal Survey. The 5 recommended missions will be part of the competition. The Cassini extended mission (EM) is continuing and is scheduled to fly between Saturn's rings and cloudtops in 2015/16 as it makes high-resolution, low-altitude gravity measurements. NASA will be participating in the European Space Agency's (ESA) Jupiter Icy Moons (JUICE) mission at a level of $100M. NASA has issued an AO and is in the process of instrument selection for this mission. JUICE will investigate Ganymede, Europa and Callisto, with an emphasis on Ganymede, and will include 2 flybys of Europa. JUICE will launch in 2022, arrive at Jupiter in 2030, insert into a Ganymede orbit in 2032, and conclude with an impact into Ganymede.

Domestic production of Pu-238 has been Congressionally approved, and a plan has been submitted outlining roles and responsibilities of both NASA and the Department of Energy (DOE). NASA will bear the burden of cost of plutonium production, while the DOE has been chartered to manage NASA's radioisotope capability. The DOE has irradiated a Np-237 target in an existing reactor at Oak Ridge National Laboratory and has subsequently produced a sample of Pu-238. The project and baseline confirmations of a complete plan are expected by December 2013. Dr. Green was pleased with progress to date. In the Discovery 2012 competition, NASA has made two Advanced Stirling Radioisotope Generator (ASRG) flight units available for use. InSight, however, is not using an ASRG, but the Discovery 2013 AO will include opportunities to use these flight units, which are to be made available by 2016. These units could be also be used by the Human Exploration Operations Mission Directorate (HEOMD) or the Office of the Chief Technologist (OCT), as well as PSD, depending upon the results of the competition. Dr. John Rummel commented that in the Discovery 2012 AO, many useful technical lessons were imparted about the utility of ASRGs in future missions. Dr. Green felt it important to note that a principal investigator (PI) must be able to justify the use of Pu-238, for use in areas such as permanently shadowed craters, for drilling in areas where sunlight is low, or in a lengthy mission in a dusty environment.

Within the MEP, NASA announced a 2020 Mars science rover at the most recent meeting of the American Geophysical Union (AGU). This mission does not represent a new start, does not require new money, and is within the guidelines of the President's current budget. NASA is currently building a Mars aeronomy mission, MAVEN, which is to be launched in November 2013 from Cape Canaveral. MAVEN will study the Mars upper atmosphere and ionosphere to determine the rate of loss of the planet's gases to space. NASA is also participating in two ESA missions: the Trace Gas Orbiter (providing a UHF Electra communications system) and the ExoMars rover (providing the MOMA instrument, an organics/molecular analyzer). PSD will continue to work with HEOMD and OCT to determine the future of Mars exploration, and has received input from Mars Program Planning Group (MPPG) and the Lunar and Planetary Institute (LPI) June 2012 workshop for future Mars missions.

The next steps in NASA's in-guide plan will be the development of the 2020 rover. There is currently much residual hardware ($200M of spare parts), and PSD is working with OCT and HEOMD, while providing opportunities for international cooperation. Dr. Green stressed that the 2020 rover adheres to the Decadal Survey in that it is a mobile rover that will conduct surface-based science at a site that will be selected to preserve evidence of life and to prepare for sample return. NASA is preparing an open letter to the community to develop a Science Definition Team (SDT). The AO, to be released in early Summer 2013, will be derived from SDT findings that will establish science objectives, a strawman payload, and an instrument suite. NASA estimates this mission to be a $1.5B (NF-class) rover, using current Mars architecture, SkyCrane technology, and rover chassis design as heritage items. Strategic knowledge gaps (SKGs), as identified by HEOMD through the Mars Program Planning Group (MPPG) process, will also be considered. NASA has already received communications from international agencies indicating their interest in participating in the 2020 rover. Dr. Andrew Steele asked if a caching design was part of this effort. Dr. Green acknowledged that sample caching, management, and handling capabilities need to be developed and are on the table for the SDT. NASA will receive the SDT recommendations on this issue and will act on it.

Dr. Green mentioned a good deal of misinformation that had been circulating in the community as to the rover's ability to make progress toward sample return. He acknowledged that there will be limits to the size and number of samples, with many considerations yet to be studied, including planetary protection, during the SDT process. In answer to a question as to the nature of cache planning, Dr. Green averred that this is the decade to establish a means of creating a multiple-sample return, recognizing that ESA's ExoMars mission is not designed to cache a sample. Dr. Penny Boston expressed concern that a compressed SDT period would limit effective thinking about caching science. Dr. Michael Meyer, NASA's lead scientist for the Mars Exploration Program, commented that this decision will be part of the SDT's recommendations, including consideration of special regions.

A Lessons Learned (LL) activity for MSL is now getting under way; team membership and terms of reference (TOR) are being finalized, and planetary protection representation is under discussion. The final report will be delivered in June 2013. Components of planetary protection under study include the rover wheels, drill bit, and sample-handling systems, and the planetary protection procedures used in their design and assembly. The MSL team independently implemented activities that may provide inputs for a planetary protection LL study; at present this is a small internal task to capture data, images and other information regarding the use of the ATP assay, among other techniques, during MSL Assembly, Test and Launch Operations (ATLO).

Dr. Green addressed the budget constraints within PSD. Funding for FY13 stands at $1.19B, representing a 21% decrement from 2012. The Mars budget line will decline through 2015 and rise in 2016 through 2020. The 2020 rover is not taking money from the R&A program, as has been rumored. The current status of PSD R&A is healthy despite the total reduction in the budget. The greatest monetary reduction will be in the 2013 flight program. The overall decrease in R&A is about 10%; PSD spent $206M in 2010, $211M in 2011, and $245M in 2012. The division is planning $228M for 2013; this represents an increase from 2011. Planetary Protection R&A for FY12 amounted to $2.54M, with a target to spend $2.4M in 2013 (6% reduction). There is additional planetary protection money that is project-specific. Sequestration may entail an 8% cut ($95M). For comparative purposes, the Cassini mission runs at $59M in R&A. This is a dire situation for PSD. NASA is also operating under a Continuing Resolution (CR), which means about 85% of the $1.19B is actually available for use. PSD, acting on principles provided by the NAC Planetary Science Subcommittee (PSS), will meet ongoing grant commitments before new selections can be made; awards will be made and announced within one month of selection. If a proposal is considered "selectable," PSD will fund proposals as money is made available throughout the year. Proposals that are not selected will simply not be funded.

Dr. Peter Doran noted that there had been no mention of Europa and asked whether it was possible to ramp up funding for a mission. Dr. Green noted that NASA was moving forward with ESA on JUICE but that no new starts were available for a NASA Europa mission; NASA does not anticipate a new start for several fiscal years. A revamped, reduced-scope Europa study was performed at the Jet Propulsion Laboratory (JPL); an orbiter mission, a multiple fly-by mission, and lander mission concepts are all possible options, one of which could be initiated later in this decade. A new start must go through an approval process in PSD, NASA Headquarters, the Office of Management and Budget (OMB), the Office of Science and Technology Policy (OSTP), and the Congress before it could be realized. ESA's JUICE mission will remain extremely important in the meantime.

Dr. Levy asked, given the budgetary atmosphere, whether any planetary budget needs could be ameliorated by closer cooperation with HEOMD and joint objectives with OCT. Dr. Green replied that

PSD is always looking for a way to create partnerships; an example is a new cooperative agreement with the NASA Lunar Science Institute (NLSI), which is evolving into a new Solar System Science and Exploration effort; the new agreement involves 7 institutional nodes. Grant sizes are $1M or more per year per group. The grants will focus on the Moon, near Earth asteroids, and Phobos and Deimos, and will include PSD, Heliophysics Division, Astrophysics Division, and HEOMD. Depending on competition outcomes, each division/directorate will provide funding as selected. OCT is still in the process of setting itself up, with a focus on optical communications, and Entry Descent and Landing (EDL) capabilities. Dr. Green felt that OCT could offer more support as defined through the SDT. He added that he has encouraged Dr. Cassie Conley, Planetary Protection Officer, to continue discussions with OCT to make the necessary connections for technology investments. Dr. Rummel commented that PSD could easily double its present technology investment without more than a 1% cut in other programs. Dr. Steele asked if HEOMD had any interest in sample handling, as it seems that this issue is not getting sufficient attention; sample integrity, periods of caching, etc., must be established. Dr. Green noted that resource utilization studies are being performed in HEOMD. Dr. Pat Beauchamp commented that OCT should be much more involved in contamination control, which requires simple system engineering that must be integrated early on. Dr. Lofgren commented that it would be necessary to evaluate geologic sampling. Dr. Victoria Hipkin noted that sample handling prototype systems are being developed in the Canadian Space Agency. Dr. Doran asked at which point might the objectives of robotic handling and human exploration be connected. Dr. Green replied that it seems clear that the future of HEOMD will be a combination of human and robotic systems and believed the new cooperative agreement is a step in that direction; the two cultures must learn how to work together. HEOMD needs PSD and vice versa; this collaboration will help advance science capabilities. Dr. Green acknowledged that planetary protection would be more important than ever on upcoming missions, and recognized the responsibility of PSD to respond to this increased need. Dr. Levy felt that the issue needed to be forced from a higher managerial perspective. Dr. Green noted that Science Mission Directorate (SMD) Associate Administrator John Grunsfeld supports this collaboration, and his relationship with HEOMD will continue to grow to marry the programs. HEOMD's Joint Robotics Precursor Activity manager, Victoria Friedensen, commented that there had been a specific recommendation from the NAC on this very issue of forging the deepening relationship between SMD and HEO.

<u>Planetary Protection Update</u>

Dr. Conley presented an overview of recent activities while reviewing planetary protection goals, driven by NASA's scientific interests. The PPO exists to ensure NASA missions do not carry Earth contamination into areas that may contain evidence of life and to prevent NASA missions from returning contaminants to Earth. The policy document governing planetary protection is NPD 8020.7 G, on the basis of which the PPO acts on behalf of the SMD AA to maintain and enforce policy. NASA obtains recommendations on planetary protection issues from the National Research Council (NRC) Space Studies Board (SSB), and advice on policy implementation from the NAC PPS. Specific requirements for robotic missions are contained within NASA Procedural Requirements (NPR) 8020.12D; future requirements for human missions are currently under study.

The role of PPS is to provide expert advice to NASA on planetary protection, specific points of policy, and guidance on programmatic issues. Recent recommendations from the November 2011 PPS meeting, which was held jointly with the ESA Planetary Protection Working Group (PPWG), included a call to renew formal international collaboration; evaluate the biological potential of the circum-Mars environment (primarily concerned with sample return from Phobos/Deimos) by means of a small *ad hoc* subgroup involving PPS and PPWG; capture planetary protection Lessons Learned from MSL; and continue joint missions with ESA. The May 2012 meeting of the PPS yielded one primary recommendation: that NASA should develop a NASA Procedural Requirements (NPR) for human extraterrestrial missions at a level corresponding to the current Committee on Space Research (COSPAR) planetary protection guidance. Furthermore, the PPS found that it would be beneficial to involve the PPO in the Mars Program Planning Group (MPPG) efforts, and concurred with the Japan Aerospace Exploration Agency's (JAXA) classification of the Hayabusa-2 mission as an unrestricted category V Earth return. PPS also recommended that NASA and ESA renew a Letter of Agreement (LoA) between the two agencies, which is in progress, as well as the production of a Lessons Learned report on planetary protection, derived from the MSL exercise.

Lessons learned from MSL should include issues with spacecraft materials and contamination control that may affect measurements made *in situ* or post-return. PPS further recommended that key elements of a bioburden accounting software package should be developed for use in the Mars Sample Return (MSR) campaign, and that a publication should be written on the use of the ATP assay compared to the NASA standard assay in order to facilitate the adoption of the ATP assay on MSR elements. Research will also be needed to approve the assessment of proposed landing sites in the context of liberation of fluids from the hydrated or frozen ground in the presence of a radioisotope thermal generator (RTG). Circum-Mars environment and joint activities recommendations from PPS were transmitted to PPO. NASA concurred with PPS recommendations on the ESA-NASA LoA, MSL Lessons Learned activities, the PPS/PPWG joint recommendation, and the planetary protection status of Phobos/Deimos. In addition, planetary protection considerations are being included in a study led by the Office of the Chief Engineer (OCE) to capture Lessons Learned from MSL. A bioburden accounting tool is now being developed at the Goddard Space Flight Center, and some ATP data has been collected and is under analysis via funding at a low level from the JPL Mars Program planetary protection lead.

In response to the May 2012 recommendation to develop a NASA Requirements Document specifically covering planetary protection for human missions, which was eventually accepted by the Science Committee and the NAC, a document has been drafted, based on COSPAR guidelines, that will be edited with HEOMD and submitted through the standard process for approval, to be signed jointly by the SMD and HEOMD AAs. In addition, discussions have been initiated regarding interest in a joint NRC-ESF study on refining requirements in the NPR -- NRC personnel believe this would be a timely activity, given NASA funding, and ESA has indicated interest in supporting the the ESF.

Updates to policy and requirements include results from an NRC study of planetary protection requirements for missions to icy bodies, which was released in April 2012. This report recommended a decision-tree approach to determining planetary protection categories, rather than a Coleman-Sagan formulation. A workshop was held in July 2012 to assess current NASA practices in the context of the report; as a result it has been concluded that NASA's current practice is in fact consistent with NRC recommendations. NASA is currently preparing a response to the NRC, and is also preparing a publication describing current NASA planetary protection rationales, in order to address the apparent discrepancy between NRC perception and actual practice.

Dr. Conley discussed the new Discovery selection, InSight, a mission that will land in the equatorial region of Mars. It is expected to be a category IVa mission with appropriate restrictions; mission planners must demonstrate in fact that the landing site is appropriate for this categorization. Programmatic concerns have arisen as to the increasing number of mission concepts that target locations of interest for planetary protection, at both Mars and Outer Planet destinations, which will require additional effort to ensure adequate oversight and consultation on planetary protection. There is also increased interest in exploration by both international and commercial bodies, which raises concerns about international cooperation, historical/environmental protection, and commercial exploration ("planetary management" activity). Prof. Gabrynowicz commented that in most of the world, commercial enterprise is not necessarily private. Dr. Conley reported that there is explicit documentation for providing pre and post-flight planetary protection measures for efforts such as the Lunar X Prize, but this is still a work in progress. Dr. Lindberg commented that even when commercial entities are not funded by NASA, they are still obligated to follow COSPAR rules. Prof. Gabrynowicz noted that there would be an ethical obligation, but not necessarily a legal one; in the case of a Federal Aviation Administration (FAA) request for a launch application, NASA typically reviews an application and recommends planetary protection measures. Dr. Conley noted that this process applies to U.S. launches and reentries but does not cover activities beyond the atmosphere.

PPS discussed the competing legalities as well as the limited regulatory reach of NASA. The national obligation is clear, but the means by which it is carried out is not. Prof. Gabrynowicz noted that Article IX of the Outer Space Treaty is very ambiguous, leaving room for wide interpretation. The NASA planetary protection budget totals roughly $2.5M, and the research program is roughly half of this amount. Dr. Conley noted that the programmatic side of the planetary protection budget has been increasing since 2011, and that PPO will not be making any R&A selections this year due to a restricted research budget. Growth in program spending has been driven by succession planning, increased mission monitoring, and international collaboration.

<u>Mars Program Planning Group (MPPG)</u>
Dr. James Garvin presented the results of the Mars Program Planning Group (MPPG), chaired by Orlando Figueroa, which was initiated in March 2012 in order to reconcile the science objectives of the planetary Decadal Survey, the President's 2013 budget, and the President's challenge to place humans in Mars orbit in the 2030s. The MPPG team was comprised of a set of community experts and chartered to provide mission options in the light of critical boundary conditions such as budget constraints through FY17, the imperative for international collaboration with particular attention to 2018/20 opportunities, and responsiveness to the Decadal Survey.

The MPPG approach to planning was based on the successful Mars 2000 plan, and was designed to move toward a more integrated relationship between SMD, HEOMD and OCT, to support both human and robotic exploration at Mars. The goal was to recognize options for a meaningful collaboration among the three, and ultimately a Mars sample return (MSR) architecture was deemed to contain the most promising intersection of objectives and strategy for long-term collaboration. A Mars precursor science analysis group (PSAG) concluded that MSR would be equally important to engineering, planetary protection, and human safety. Discovery-driven science pathways were identified and used to frame the MPPG results.

MPPG considered the use of both strategic and competed, stand-alone missions to carry out Mars missions, and utilized a traceability matrix to evaluate candidate pathways, including missions and goals recommended by the Decadal Survey and the Mars Exploration Program Analysis Group (MEPAG), as well as risk postures and potential costs associated with each pathway. On the basis of MPPG analysis as well as input from the community at a June 2012 workshop on Mars concepts (results of which may be viewed at www.lpi.usra.edu/meetings/marsconcepts2012), MPPG concluded that sample return is the best pathway in terms of scientific return, risk, available and mature technologies, pace of funding, and infrastructure investment.

MPPG identified capabilities needed for humans at Mars in the 2030s, divided into epochs of first use (2012-2024; 2024-2033; 2033+), and points of intersection among HEOMD, OCT, and SMD. Joint activities envisioned technology developments in areas such as high-data-rate communications, and *in situ* resource utilization (ISRU) demonstrations. Potential orbiter/lander scenarios were considered, including science payloads on a 2024+, single-shot sample return mission. Mars sample return and recovery during early crewed operations in an Orion-class system beyond Earth orbit was also considered as a feasible candidate, wherein a sample canister could be captured, encased, and retrieved telerobotically; this concept deals with some critical planetary protection concerns by "breaking the chain" of contact, robotically. Dr. Garvin noted that the mass of fuel to send and return four humans to and from Mars is 375 metric tons.

MPPG also considered key technologies that would be necessary for EDL, ISRU, and Mars Ascent capabilities. The key functions in a sample return architecture were construed as sampling, retrieval, return, and receiving. Sample return was considered in three-, two-, and one-launch scenarios, including a solar-propelled return of a Mars sample in two- and three-launch concepts. The common aspects of all pathways considered included maintained heritage, the use of SkyCrane technology, and solar-electric propulsion (SEP)-based orbiters for sample rendezvous and return. MPPG studied four rover options: a rebuilt Mars Exploration Rover (MER) (Rover A); a MER with volume growth (Rover B); an MSL chassis with MSL spares (Rover C); and a Rover C with a mated Mars Ascent Vehicle (MAV) (Rover D). Formal estimates were performed for all rover concepts except Rover D. Orbiter concepts included relay-only, traditional science and relay; sample return orbiters; and round-trip science with sample return. Estimates of these latter mission concepts ranged from $0.2B to $0.8-0.9B.

Arguments supporting the launch of an orbiter launch to Mars in 2018 include energetic favorability in the 2018 dynamics. A rover in 2018-20 would also best preserve key competencies, such as end-to-end EDL and surface exploration. Sample options provided by MPPG could also be "mixed and matched." These options, scored with figures of merit, were provided by MPPG to NASA management and to the MEPAG in late August 2012. Options presented represented in many cases a 50% reduction in cost compared to Decadal Survey concepts. The study also considered the contributions to R&A and Education and Public Outreach (EPO). The report was completed in October and will be released by the Agency shortly. Dr. Garvin reiterated an invitation to the community to join the SDT for a Mars 2020 rover mission.

Dr. Rummel commented that a proposed Beyond Earth Orbit (BEO) retrieval appears to be completely politically motivated and ties MSR to a potentially large and costly HEO project. Human flight ratings versus robotic flight ratings also make a tremendous difference in planning. NASA cannot protect the Earth from large-scale consequences in a human sample-return scenario; a human-based sample return scheme does not seem to be a rational approach. Dr. Garvin commented that MPPG concluded that samples parked in Mars orbit, waiting to rendezvous with humans in 2030 and 2035, was considered too difficult for HEO planning, as HEO is intensely focused on the Orion program. Dr. Steele commented, in terms of safety, that the biggest risk is getting off Mars; NASA has never done this. BEO also will require considerable technology development, which was not spelled out in the MPPG concepts. Dr. Garvin agreed that the risk is very large and hard to adequately categorize, and that risk assessment was critical to sample protection and planetary protection. Dr. Steele further recommended that NASA consult all the agencies involved for sample analysis to get a better idea of what is realistically available in terms of risk, cost, and lead times. Dr. Garvin agreed that there is much more work to be done.

Dr. Levy noted that as NASA looks ahead to ambitious aspirations, there seems to be precious little in international planning, particularly in human space exploration; as such, NASA is missing a serious opportunity to learn how to carry out Mars Sample Return. International efforts seem to have fallen behind, especially when compared to the successful Cassini collaboration. Dr. Garvin agreed that the program requires international involvement but that budget factors have led to great challenges in maintaining international relationships. He cited the several international instruments on the Curiosity rover, including a neutron detection instrument, DAN (Russian), a meteorological package (Spain, Denmark), APXS (Canada), and the SAM instrument (France, et al.). In 2000, the Mars program was fully international. However, both budgets and politics have changed since then. Dr. Hipkin remarked that the international Mars planning group (iMars) had been very successful in 2008/9 and that early engagement would be greatly helpful in future international collaborations. Dr. Boston commented that BEO seems to be a very bad idea, as it introduces yet another node for contamination and/or confounding signal without the added benefit of an off-Earth analysis. Dr. Garvin responded that the intent is to keep the sample contained throughout the process and that it would be easier to retrieve a sample from a stable space (such as BEO) than within a wholly new, highly risky system to return humans to Earth. Dr.

Lindberg felt that it would be much more preferable to return a Mars sample through entirely robotic means.

InSight: Science and Mission Overview

Dr. Sue Smrekar initiated a multi-part presentation on the Discovery mission, InSight. The goal of the mission rests on regarding Mars as the key to understanding the early formation of the Earth; it is uniquely qualified for the study of common processes that shape all rocky planets and govern their basic habitability. InSight will measure the crustal thickness of Mars, the layering of different compositions, mantle behavior (convection, partial melt generation), and the size and density of the planetary core, to yield insight into planetary development. The mission will employ single-station seismology; precision tracking to measure precession of planet; and heat flow monitoring via an innovative self-penetrating mole, that will burrow 3-5 m below the Mars surface. All instruments have more than 10 years of development, including a deep space transponder and the seismic experiment for interior structure (the SEIS instrument, from CNES). InSight is built on flight-system heritage from the NASA Phoenix mission, with some of the same personnel and procedures, and the same spacecraft. Launch is scheduled for March 2016, arriving at Mars in September 2016 via a type 1 transfer, and a 6.5-month cruise period. Routine operations are to last for one Martian year. The seismometer will begin acquiring data on Sol 36 of the mission. The spacecraft will land in Elysium Planitia, at latitudes limited to 2°S to 5°N, avoiding rocky areas (defined as a rock abundance of less than 10%).

A rationale was presented to support the preliminary characterization of the InSight mission as a Category IVa, according to NPR 8020.12D. A formal letter of categorization and white paper detailing the rationale was sent to NASA Headquarters last week. Planetary protection requirements for a Category IVa mission include: a total exposed surface bioburden of landed hardware that shall not exceed $3X10^5$ viable spores at launch, carried out with a variety of cleanroom procedures and microbial reduction techniques. Planetary protection implementation procedures will include preparation of the required documentation, trajectory biasing, and calculating the probability of failure of EDL, as required. Microbial burden reduction will use alcohol wiping, heat sterilization, vapor peroxide microbial reduction where appropriate, and venting of electronic modules through HEPA filters.

The heritage hardware that will be used for InSight will include the Phoenix flight system, an aeroshell thermal protection system (TPS) similar to that used for MSL, and the same parachute manufacturers that were used for the Phoenix mission. Payload assembly is ahead of the flight system buildup, therefore standard planetary protection project documentation and an expedited need for planetary protection guidance will be needed; this effort is being mitigated with payload-specific planetary protection plans that are currently in draft, also based on Phoenix heritage. InSight will utilize an Atlas V, Delta V or Falcon 9 launch vehicle, while incorporating Lessons Learned from previous missions. The manufacturing process will allow needed microbial reduction of aeroshell structure and parachute in its canister, and dry-heat microbial reduction (DHMR) credit taken for high-temperature manufacturing processes whenever possible.

With respect to the penetrating HP3 mole, the mission team has assessed the driving planetary protection factors for creation of a special region, based on MEPAG findings including temperature (-20°C) and water activity threshold (0.5) parameters that could possibly support life and its propagation. Dr. Troy Hudson presented the features of the HP3 instrument, explaining the several assumptions to support the conclusion that an internal HP3 fault-protection logic circuit would prevent excessive temperature increases, and any heat increase during mole operation would be short-lived. The mole's electronics uses an FPGA code loop that senses unacceptable temperature increases, which will automatically stop hammering. Factors surrounding the operation of the mole, low temperatures anticipated in subsurface (mostly below the -20°C threshold for microbial activity) and the aridity of the Elysium region, (water activity measurement based on Odyssey GRS data) would argue against creation of a special region. Dr. Hudson presented a detailed numerical model indicating transient temperature rises of less than 10°K for hammering and less than 20°K for heating. Conservative calculations according to GRS data indicate that no more than 50 mg H_2O/g soil would be liberated in mole operations. Water activity has been calculated to be far below microbial viability threshold.

Dr. Rummel asked whether the team had tested their assumptions. Dr. Hudson replied that mole operation and thermal conductivity measurements will be conducted in low thermal conductivity materials in various testbeds at JPL that reach 2 meters, which is short of the full 5 meters planned at Mars. The mole will be tested in full operation, including penetration with passive temperature monitoring, while recognizing that the conductivity on Mars will take place in a lower pressure environment. The mole is a monolithic body about the diameter of a quarter. Inside is a motor attached to a rotating shaft, which slowly knocks into the soil at about 1 cm per strike. It is expected that there will be a number of opportunities to place the mole, with a scientific tether that has sensors embedded along its length, to monitor subsurface temperatures. If the probe obtains less than a full year of data, modeling can be used for extrapolation, but it was noted that once the mole is placed it cannot be extracted.

Dr. Kminek made several observations: the correct measurement temperature parameter for assessing special regions is -25°C, not -20°C, and the Odyssey GRS data on Mars hydrogen content is only good to 1 meter of depth. Dr. Hudson countered that assumptions were based on a best fit to a model, and that the assumption is that the hydrogen distribution continues to depth. It is also assumed that the regolith is quite porous and that the hydrogen abundance of 5% will be governed by the cold temperatures. Dr. Conley suggested obtaining observational spectral analysis of recent craters on the Mars surface to bolster these assumptions. The proposed site is too dusty for spectral observation, which would require a large crater of very recent vintage. The team has looked at every available HiRise data point, but MRO has not included the area of interest to date. There have been no bright or dark (flow) streaks observed in the proposed ellipses; however, HiRise coverage of the region is limited. Dry heat microbial reduction and alcohol wipe-down will be used to sterilize the mole; however the tether will not withstand heating and will be wiped down to requirements for a Category IVa mission. The impact probability analysis for upper stage is being carried out by the launch vehicle side of the mission, similar to what was done for MSL.

Mars Science Laboratory: Planetary Protection Lessons Learned

Mr. Perry Stabekis of Genex Systems presented lessons learned from the MSL mission from a PPO planetary protection perspective. MSL was initially categorized as a Category IVc mission, which would have allowed any site on Mars to be explored, including special regions. Curiosity is the cleanest rover that has ever landed on Mars; the total number of spores on accountable surfaces was assessed at 5.64×10^4.

The MSL planetary protection team was characterized as a good mix of seasoned and young professionals, all of whom worked together well throughout the multiple assays and cleanings required during a long ATLO period; the team counted almost 50,000 plates. The team also improved upon and streamlined previous work that had been quite labor-intensive. A conclusion drawn from this observation is that seasoned professionals, combined with frequent and numerous assays, were essential to the mission. An improvement in this area would be mandatory training in planetary protection, especially for Category IV missions.

Mr. Stabekis said that despite some improvements in the efficiency of operations, the MSL team was very short-staffed. Previous smaller projects actually had had more personnel per mission. Limited staffing at NASA Headquarters was also the case during MSL development. As a result, he said, some monitoring functions suffered due to lack of presence. Again, compared to earlier missions such as Viking (4.5 full-time employees; FTEs), MSL had far fewer personnel (2 FTEs), resulting in some details going unchecked, such as paperwork related to the sterilization treatment and recontamination measures for the wheels and drill bits, and the late discovery that blankets had been installed inside the heat shield. This change rendered 34 square meters of the heat shield inaccessible for assays; verification samples could only be taken from a small subset of the heat shield. While staffing issues contributed to the problem, the PPO found the main issue contributing to this oversight to be poor communication. It is possible that requirements for planetary protection signoffs at particular steps might have prevented the problem. Quality Control and Quality Assurance (QA/QC) teams normally take this responsibility for other project requirements, but not planetary protection. Mr. Stabekis said some things fell through the cracks. Mr. Stabekis said this disconnect can be improved through better interaction and communication between engineers and QA/QC staff, as well as more staff *per se*. Dr. Kminek commented that the PPO should have ready access to all documentation according to NPR 8020.12D, section 2.4.1. In terms of team integration, Mr. Stabekis described good relationships that were at times at cross-purposes. The only way to address the sterilization issue is to have more independent checks, he said. Dr. Rummel added that it was important to remember how complex the mission was: 14 instruments had to be integrated, a new record for a mission. Mr. Stabekis concurred that the primary Lesson Learned in this instance is that the staffing of a Category IV mission must be better scrutinized; a member of the planetary protection team should be assigned the responsibility to attend all related meetings and handle the interfaces of the project. He said that it is also imperative that newer members be trained in planetary protection, preferably before more experienced colleagues leave the project. He stressed that the PPO must also be permitted to hire more staff: two FTEs are a minimum, especially as the Agency begins to deal with more restricted planetary protection category missions, such as Mars sample return.

Mr. Stabekis said that all Program Executives (PEs) and Program Managers (PMs) must have access to documentation and operations. The PPO found the MSL team to have attempted to impose arbitrary limitations on the number of PPO personnel involved in verification assays, which restricted viewing of important operations. Mr. Stabekis felt there were unreasonable restrictions in access to hardware that interfered with the conduct of proper verification assays. Dr. Lipps commented that it seems that this is a fundamental problem with NASA, and it implies that we are sending unsterilized spacecraft to Mars. Mr. Stabekis felt that this was an extreme view, in that the spacecraft was indeed documented to have been the cleanest sent to Mars since the Vikings. However, he believed that the PE did not prove helpful in mediating the conflict. Dr. Levy added that it was important to emphasize the mandate of responsibility in this discussion.

Mr. Stabekis said the issues surrounding recontamination of the drill bits and wheels were mishandled. The previously sterilized drill bits were removed from containment, and were re-assayed for contamination and re-contained, while one bit was placed in the drill in a clear violation of planetary protection requirements. This configuration change was communicated to the PPO in August 2011 (against a November launch date), and the project subsequently requested a deviation which required a very accelerated response on the part of the PPO. Because the choice of the landing site was Gale Crater, the only site appropriate for a Category IVa mission, the planetary protection requirements were met by MSL; the mission was re-categorized from IVc to IVa within two months of the launch. If the landing site had been different, the categorization would not have been met, and this situation would have required re-sterilization of drill bits and very likely a launch delay. Dr. Lipps noted that it seems that authority was not properly enforced. Dr. Levy commented that the problem could have been much worse, indicating that the level of planetary protection enthusiasm is not as high as it should be, and therefore needs to be reinforced from the Headquarters level. Dr. Steele asked if there were procedures in place for the PPO to rapidly respond in these cases. Mr. Stabekis stated that all projects and programs know they can refer problems to the PPO but believes there is a culture of resistance against planetary protection requirements.

Mr. Stabekis said that the MSL mission is prohibited from introducing any hardware into special regions:

fluid-formed features such as recurring slope linae are prohibited. He said the re-categorization could affect the integrity of the rover science as it pertains to the search for evidence of organic compounds indicative of habitability on Mars. This brings into focus the issue of what constitutes a "life detection" experiment and who is responsible for making the determination. Mr. Stabekis said more detailed language in the NASA documentation should be included that makes clear what planetary protection requirements are and should highlight the importance of the PPO in program management issues. Dr. Rummel recommended that these planetary protection lessons learned be fully incorporated into the NASA-wide MSL lessons learned report. Dr. Lindberg recommended that PPS go further than Mr. Stabekis's recommendation to develop corrective actions. Dr. Levy felt that would be better to wait for the formal LL report. Dr. Michel Viso commented that the international partners, other than ESA, had not been warned about the MSL re-categorization. Dr. Conley agreed that NASA should have communicated this information earlier.

December 20, 2012

Overview of the Day

Dr. Levy opened the meeting.

Update on European Space Agency Planetary Protection Activities

Dr. Kminek provided an update on recent ESA planetary protection activities. Current research and development (R&D) efforts at ESA include an analysis of the Jovian and interplanetary micrometeoroid environment affecting the probability of impact analysis required for some mission types. There are a number of micrometeoroid models that give reasonable results to within 1 AU of Earth, but they are difficult to extrapolate to Mars and Jupiter. Within MSR studies, ESA industry studies have identified the impact of the micrometeoroid effects on the heat shield used on the return capsule as critical element in the evaluation of Earth return safety (i.e. assurance of not releasing particles from Mars). The European JUICE mission, which will include two Europa flybys, identified the effect of the Jovian micrometeoroid environment as critical to demonstrate that the flight system reliability during the critical mission phases in the Jovian system. Therefore ESA has initiated studies to update the respective models supporting JUICE and MSR activities.

A breakup/burn analysis tool, which can be used to demonstrate bioburden reduction during Mars atmospheric entry, is also being developed. This is a modification of the current ESA SCARAB (Spacecraft Atmospheric Reentry and Aerothermal Breakup) Re-Entry Analysis Tool, which has proven to be a good validated tool for Earth re-entry. A new SCARAB-M model that is being developed for Mars will utilize both US and European climate databases; it is expected to be finished by the second quarter of 2013. SCARAB-M will include a full 6-degree-of-freedom SCARAB tool, that provides full debris field approximation, and a simpler version that will be made available to projects in phase A and B1 activities. The full tool is being designed for use at Critical Design Review for verification purposes.

An in-flight containment system for MSR is currently in testing phase for seals and an in-flight verification system. Some breadboards have been manufactured using flight-like materials such as titanium. The initial effort is to be finished by the first quarter of 2013, after which ESA intends to continue to the next level without a gap in activity.

A biohazard assessment of samples returned from Mars, to determine relevant sub-samples to evaluate safety for release from containment, is currently under way. ESA is running two independent teams in parallel, and has already seen differences in approaches that will be instructive. Completion is expected by the end of 2013. Dr. Levy asked if there were an easy way to determine a level of confidence. Dr. Kminek replied that a parametric analysis will have to be performed in order to determine a level; the requirements will be determined later based on a review of the study results. A feasibility study that is to begin next year will consider a double-walled isolator as a concept for use on Earth. ESA has also decided to begin, in 2014/15, a study on how to manipulate samples in isolation.

ESA is providing funding for statistical analysis of data for a new bioburden assessment and analysis tool; there is currently a test version that will help projects to plan for assays. The tool is based on experience gained by the Mars Pathfinder and MER missions. A final version for project use is planned for the first quarter of 2013, which will also be useful for documentation purposes; this effort is being conducted jointly with GSFC.

An updated version of a bioburden wipe assay validation, which will use fewer consumables and be more rapid, is being assessed jointly with Kennedy Space Center (KSC).

New R&D for 2013 includes determining inactivation levels for life forms, through heat and ionizing radiation, in preparation for a Phobos sample return mission. At present, it is not possible to categorize a Phobos sample return as an unrestricted return; there will be a need to look at levels that could be acceptable for extraterrestrial life. A second study will be conducted on the effects of hypervelocity impacts, taking into account the results of the Melosh *et al*. study, to evaluate temperature and pressure effects on the projectile. A feasibility test has been completed, which will be followed by comprehensive test activities.

Mission extensions that have been evaluated from a planetary protection perspective include Mars Express, which is in a highly elliptical stable orbit that is easily stable beyond 50 years. An orbit change would change the timing of its impact but not the event. As currently planned, the spacecraft will eventually will impact Phobos several hundred years from now. After the Rosetta end-of-mission, the Rosetta spacecraft will be co-orbiting the comet around the sun; mission analysis shows closest Mars approach of comet/spacecraft is 94 million kilometers in the time period of 50 years after launch – and therefore meets the Mars impact probability constraint.

ESA has received a proposal from the Herschel mission's science team proposed impact on lunar poles and coordinated observations of released volatiles as final disposition option for the spacecraft. This proposal is under evaluation by ESA. The science case has been reviewed. The mission was asked to provide an organic materials inventory, with a declared organics list and a chemical analysis of fuel (hydrazine). The project has provided these data and has complied with requirements, which has been approved, should the mission be carried out. Dr. Rummel commented that he did not understand what new or important science the impact data would yield; it appeared to be a hammer looking for a nail. Dr. Pieters noted that a broader issue is protecting the science on the surface of the Moon, as contaminating lunar the surface with impacts can interfere with future experiments. These impacts can affect the LADEE mission, which is to examine the pristine nature of lunar dust in the exosphere. The effects of these impacts are unknown in terms of how long debris lingers in the exosphere. Dr. Conley commented that the LADEE team felt the Herschel impact might be an interesting event. Dr. Pieters replied that another portion of the team feels that the impact would be detrimental, particularly as the dust environment at the lunar poles could be disturbed. Dr. Conley requested further information regarding LADEE team concerns. Dr. Rummel suggested referring the science preservation issue to both the PSD and APD. Dr. Kminek noted that the Herschel project has met all the applicable planetary protection requirements for a potential lunar impact of the S/C and therefore this option is in line with the current COSPAR/ESA/NASA planetary protection requirements; the organics inventory would be provided at the next COSPAR meeting but could be publicized earlier, if necessary.

The European Science Foundation-European Space Sciences Committee (ESF-ESSC) report on Mars sample return backward contamination, which contained strategic advice and requirements, was distributed to subcommittee members. Of the report's 11 recommendations, Dr. Kminek highlighted the report's recommendation to use the best available technology as a precautionary principle in sample return, as it uncertain whether the returned material will be hazardous; this is in agreement with the 1999 NRC report on the same issue. The ESF-ESSC report considered the possibility of self-replicating organisms, but was also concerned about viruses and gene-transfer agents (GTAs). The report relied on a concept of a level of assurance of not releasing a particle of a certain size, stating it was reasonable to accept that less than 10^{-6} is an appropriate probability for the release of 10-nm particle, based on what is known about viruses and GTAs, with some margin provided to allow for some additional criteria. Asked whether these numbers had been incorporated in the subsampling activity, Dr. Kminek replied in the affirmative, and added this consideration had also been used for the flight containment system.

ESA-PPWG has endorsed the report recommendations with minor adjustments. Dr. Kminek invited the PPS to read the report and to discuss it at the next meeting, possibly with a study lead from the ESF. Dr. Kminek added that ESA/NASA could make a joint submission to COSPAR. Dr. Levy agreed, and noted that it would also be useful to hear a description of the planetary protection enterprise in Europe in terms of scope, size, and budget.

Discussion

The PPS briefly discussed various issues. Dr. Rummel commented that a widely based international forum on planetary protection issues is needed and suggested that PPS invite more international participants to the effort, by renewing requests to the Japanese, Australians, Indians, and if possible the Chinese; this will become more important as NASA moves toward human space flight. Dr. Levy cautioned that meetings must be kept to a scale at which work could be done. Dr. Lindberg suggested that the periodic joint ESA-PPS meeting be expanded to also include the FAA, especially with regard to the Moon. Prof. Gabrynowicz recommended a representative from the State Department, Mr. Ken Hodgkins. The subcommittee discussed the possibility of meeting outside the U.S.

Planetary Protection Office Technology Studies

Mr. Andreas Frick presented the results of a recent study aimed at identifying needed strategic research and technology development activities, performed in partial response to the PPS' ongoing deliberations regarding improving NASA's capabilities in planetary protection. Benefits of this effort would be to maintain program continuity and stability, better align activities with NASA's strategic goals, and to complement mission-driven technologies with capabilities-driven technologies.

Methods for implementation included a consideration of microbial reduction and cleaning methods such as DHMR, radiation, physical cleaning with solvent wipes, VHP (vapor phase hydrogen peroxide), SCC (supercritical CO_2 snow; under study by both JPL and ESA), and EtO (ethylene oxide, used in the medical industry but not in current planetary protection methodologies). Asked if any thought had been given to efficiencies, Mr. Frick responded that most concerns had been on materials in the critical path. Recontamination control and sample handling systems such as clean room aseptic assembly and integration (pioneered by Beagle 2), biobarrier HEPA filtration (Viking, Phoenix), and restricted handling sample containment were also considered. Dr. Rummel clarified that the biobarrier systems had been developed through a separate Mars technology line. Dr. Lindberg added that this exercise illustrated the value of a synergistic R&D activity, developed in advance of a need.

Operational analysis tools included burn-up and break-up (BB) analysis (MRO, MAVEN); trajectory and impact analysis, MSL upper stage, Juno), and planetary radiation environments (Juno, considered for MSL wheels/drill for recontamination). Dr. Buxbaum pointed out the BB analysis has been brought to further maturity at both JPL and Lockheed Martin.

The report considered cross-cutting research and support activities in component and material availability, biological methods, resistant spores and genetic inventory, habitable planetary environment and spore transfer, and systems engineering. Concepts for human space exploration included consideration of mission architecture [operational controls for zones of minimum biological risk (ZBRs)], contamination control methods of human missions (EVA suites, *in situ* sterilization of robotics and tools), and crew health monitoring (International Space Station research). Dr. Conley noted that diagnostic procedures need to be better understood in terms of what they mean to astronaut health. Planetary protection activities for MAVEN, InSight, Phobos-Grunt, Hayabusa-2, and OSIRIS-Rex, especially in terms of organics, are of high concern for all of these missions. Rough cost estimates for system sterilization were put at $1-2M /year for 3-6 years. A potential work breakdown structure was presented: Systems Engineering, Scientific Research, Knowledge Management, Technology Development. Dr. Levy noted persistent concern regarding the magnitude of PPO resources to carry out these activities.

Proposed strategic priorities include full-system sterilization to enable life detection missions, sample containment and analysis for MSR, coordination with HEO architecture groups, and ongoing tasks such as genetic inventories and assays. Mr. Frick expected that study results would be published shortly. Dr. Lofgren recommended compilation of a list of show-stopping lack of technologies with respect to a Mars sample return mission. Other questions to be considered: what really needs to be done before NASA can carry out an MSR mission; how can a Mars sample return facility both contain and detect life? Dr. Levy commented that a body of collective, coherent knowledge that can be transmitted to new researchers/engineers must be developed. Dr. Kminek noted, regarding human space exploration, that human immune system changes occur in space flight, and that without extensive life science research, one cannot predict how humans might be affected by sample return. Dr. Lofgren mentioned a long-term project at JSC to monitor astronauts against controls. Dr. Conley noted that the issue of associated microbes is still nascent. Dr. Kminek commented that he did not see a ramp-up in HEO to study health effects in humans with regard to sample return. Dr. Rummel noted that one problem with ISS is the limitation to what can be emplaced, which is currently very curtailed; the Health and Medical Office is loath to add to the research burden of the ISS crew.

JPL Technology Studies

Dr. Pat Beauchamp presented details of assessments of planetary protection and contamination control technologies for future planetary science missions; these assessments were a NASA-wide effort following on from a 2005 study performed at JPL. The purpose of the assessments were to provide information to PSD since JPL's 2005 report, spending more time on both contamination control and planetary protection methodologies, and also addressing issues in the most recent planetary Decadal Survey. It is a mission-centric report, focusing on scientific integrity, keeping mission costs in check, and returning high-quality samples that are free from biological and organic contaminants, while recognizing that contamination control and planetary protection are related but approached differently by engineers and scientists.

The study team, led by Andrea Belz, collected information describing the state of the art in planetary protection. A steering committee created findings and recommendations, which focused on robotic, and not human, operations. The findings emphasized development of an MSR facility, which will require 15 years of development and certification in advance of its completion. Dr. Levy noted that it would be difficult to build up a cadre of people for an abstract concept. Dr. Buxbaum referenced an industry studies paper in *Astrobiology*. Dr. Kminek commented that the iMars team had concluded that such a facility should be established within an active research environment, well in advance of actual sample return.

The 2011 report (http://solarsystem.nasa.gov/scitech/display.cfm?ST_ID=828) found that there has been progress since 2005, particularly in standard and extended DHMR, and VHP sterilization techniques. In terms of bioburden detection, both standard and rapid spore assays have been validated. A genetic inventory effort has been completed, and many organismal populations are now understood for cleanrooms. New models exist for contaminant transport within the Mars and Europa systems. Isolation technologies such as biobarriers have been implemented, mostly at the program level, and aseptic facilities have been identified for assembly. There is now a proof-of-principle design for a MSR facility.

Systems engineering was found to be woefully lacking for contamination control and planetary protection technologies; as a result, it has been recommended that a systems engineer who understands planetary protection should be inserted into the team as early as possible in the mission development effort. This would be in addition to having a separate person to actually monitor the planetary protection activities.

In terms of technology development, the report found a need to develop a streamlined approval process in order to determine the effect of non-uniform molecular contamination on micron and sub-micron particle contamination.

The report further recommends that NASA solicitations for early instrument technology development should include requirements for education and training in planetary protection, which should be offered to all interested proposers. Dr. Kminek commented that at ESA, training needs are identified each year, including training in planetary protection. NASA also has a planetary protection course listed in its APPEL offerings. Dr. Lindberg commented that there is a perennial problem in NASA in sharing resources between civil servants and contractors. Dr. Levy proposed offering online courses. Dr. Beauchamp added that engineers must be engaged in learning about planetary protection. Dr. Lindberg commented that mission teams should delineate planetary protection responsibilities in both executing and auditing measures.

The report found that contamination control experiences are not being captured, as many practitioners are retiring, and recommended that NASA at minimum publish a white paper, which should be continued as a living document. PPS encouraged more cross-fertilization with the OCT and OCE on planetary protection technologies. Dr. Conley noted that Dr. Andy Spry is funded by the PPO to interact with OCT and OCE.

NASA Administrator Charles Bolden joined the subcommittee proceedings briefly and commented on the discussion. He agreed that NASA must have representation from OCT, OCE, and the Office of the Chief Health and Medical Officer (OCHMO) in the planetary protection effort, and fully supported early engagement of planetary protection in NASA missions. The involvement of the Office of Safety and Mission Assurance (OSMA) and the Office of the Chief Scientist (OCS) also came up in the ensuing discussion [attribution uncertain]. Dr. Lindberg encouraged NASA to seek planetary protection funds from the various relevant organizations. Dr. Lofgren recommended capturing ideas from new sources. Dr. Boston, citing past inputs to the OCT roadmap, remarked that OCT has been reluctant to pick up the mantle and that perhaps the Planetary Protection Office needs its own roadmap.

Working Lunch Discussion

The subcommittee discussed various issues, including maturing instruments with planetary protection needs within the PSD Research and Analysis funding line MATISSE, and participation in the MSL Lessons Learned activity. Dr. Lindberg noted that it seemed apparent that there are deficiencies that are still not being addressed in ATLO, particularly with respect to planetary protection. He added that the PPO should communicate with as broad a constituency as possible, so that organizations including OCE and OCT should participate as stakeholders in the planetary protection process. Dr. Conley reported having contributed a list of candidates for planetary protection representation to the MSL effort, which has yet to be acted upon. Dr. Levy recommended formulating a letter to the MSL panel requesting visibility. Dr. Rummel agreed to draft the letter. Dr. Boston felt the problem had more to do with gross understaffing and underfunding of planetary protection, and that obtaining representation on the MSL Lessons Learned panel would not solve the larger problem. Dr. Kminek remarked that despite the public attention to some MSL planetary protection issues, the planetary protection team within the MSL project had done a very good job and should be acknowledged for having done so.

Joint Robotic Precursors Activity (JRPA)
Ms. Victoria Friedensen presented an update on HEOMD's activities in joint robotic mission development. JRPA (Joint Robotic Precursors Activity) is co-funded with SMD and is mandated by OMB to inform the selection of human destinations at the Moon, Near-Earth asteroids, and Mars, including Phobos and Deimos. HEOMD is developing an integrated set of strategic knowledge gaps (SKGs) about these destinations, funded at $30M/year to develop instruments, R&A, strategic studies and workshops, and targeted missions.

JRPA is working to create project plans with milestones and deliverables and is actively working with the SMD AA to vet these plans. JRPA operates by guidelines to ensure that it does not interfere with selected SMD missions and instead leverages them by adding bandwidth, secondary payload, and supporting instrumentation. JRPA is not a technology development activity, but it does deal with ISRU. Proposals to the program are vetted through a steering committee. SKGs will be used to inform mission boundary conditions and design. The NASA Lunar Science Institute (LSI) is being expanded to address some of these SKGs. Radiation, regolith and reliability are the three themes that will enable human exploration across destinations. JRPA is studying ISRU as a means of reducing mass and would like to validate this assumption by characterizing volatiles on the Moon, to determine whether ISRU can be used on Mars, by either atmospheric processing or by using water sources (hydrated regolith) on the surface. HEOMD is participating in the 2020 Mars mission and is well aware of planetary protection requirements. JRPA is considering ISRU for shielding at Mars and has engaged the lunar, Mars, and planetary AGs.

In 2013/14, JRPA will carry out a Lunar Mapping and Modeling Project, a web-based education application designed to expand available lunar data products as well as the NLSI. JRPA is also participating in a Goldstone radar capability for imaging asteroids, leveraging an existing DOD application to enable one-meter resolution, and RESOLVE, a lunar ice-prospecting payload being carried out in partnership with Canada.

JRPA is not at the point of having an identified instrument and is mostly leveraging previous investments. ISRU has moving parts, and a heater, and the program does recognize that this would be a planetary protection concern. In terms of maturity, a lunar ISRU package is ready to be flown but not without challenges for long-term autonomous operation. A better demonstration of this capability needs to be built up before it is used on Mars. JRPA's long-term goal is to fill as many SKGs as possible.

Public comment period
No public comments were noted.

Discussion
The subcommittee discussed ways in which the PPO budget might be enhanced through a well-developed recommendation. Dr. Conley remarked that the office really needs more staff, and the visibility of and engagement with planetary protection measures must be addressed. Dr. Beauchamp cited JPL as an available resource for Dr. Conley. Dr. Lindberg noted that schedule and number of personnel proved to be a relatively more complex problem for MSL as compared to the Viking era. Dr. Rummel felt that the principal difference between the two eras had been in the management: projects must have direction from the management to ensure planetary protection is incorporated, and Rummel said he believed this was not the case for MSL. Dr. Beauchamp also pointed up the importance of a balanced workforce as well as staff morale. Dr. Lipps requested that Dr. Conley prepare a list of needed resources.

PPS concurred on the spirit of a letter requesting planetary protection representation on the MSL Lessons Learned panel. Dr. Lindberg thanked Dr. Levy for creating a collegial atmosphere within PPS. Dr. Lofgren supported the development of a planetary protection roadmap. Ms. Kaminski reminded PPS members to file their 450 forms, and informed the subcommittee that Gale Allen would be taking over her position.

The meeting was adjourned at 2:20 pm.

Appendix A
Attendees

Planetary Protection Subcommittee Members
Eugene Levy, *Chair Planetary Protection Subcommittee*, Rice University
Penelope Boston, New Mexico Tech
Peter Doran, University of Illinois/Chicago
Joanne Gabrynowicz, University of Mississippi
Victoria Hipkin, Canadian Space Agency
Gerhard Kminek, European Space Agency
Gary Lofgren, NASA JSC
Robert Lindberg, University of Virginia
Jere Lipps, University of California, Berkeley
Jon Miller, University of Michigan
Carlé M. Pieters, Brown University (telecom)
John Rummel, East Carolina University
Andrew Steele, Carnegie Institution of Washington
Michel Viso, CNES

Catharine Conley, *Planetary Protection Officer*, NASA HQ
Amy Kaminski, *PPS Executive Secretary*, NASA HQ

NASA Attendees
Gale Allen, NASA HQ
Marc Allen, NASA HQ
Pat Beauchamp, NASA JPL
Charlie Bolden, NASA HQ
Janice Buckner, NASA HQ
Karen Buxbaum, NASA JPL (telecom)
Doris Daou, NASA HQ
T. Jens Feeley, NASA HQ
Victoria Friedensen, NASA HQ
James Garvin, NASA HQ
James Green, NASA HQ
Lisa May, NASA HQ
Michael Meyer, NASA HQ
Marion Norris, NASA HQ
Michael New, NASA HQ
Mitch Schulte, NASA HQ
Bette Siegel, NASA HQ
Heather Smith, NASA HQ
J. Andy Spry, NASA JPL
George Tahu, NASA HQ
Mary Voytek, NASA HQ

Non-NASA Attendees

Linda Billings, George Washington University
Andreas Frick, George Washington University
Bill Mackey, CSA
Rakesh Mogul, SETI Institute
Mangala Sharma, Department of State
Perry Stabekis, Genex Systems
Tom Statler, NSF
Joan Zimmermann, Zantech IT

Appendix B
NAC Planetary Protection Subcommittee Membership

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

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 Gabrynowicz
Director, National Remote Sensing, Air and Space Law Center, and Research Professor of Law
University of Mississippi School of Law

Robert Lindberg
Research Professor
University of Virginia

Jere Lipps
Professor and Curator
Department of Integrative Biology & Museum of Paleontology
University of California at Berkeley

Gary Lofgren
Lunar Curator and Planetary Geoscientist
Johnson Space Center, NASA

Claudia Mickelson
BSP Deputy Director, Office of Environment, Health & Safety
MIT

Jon D. Miller
Center for Political Studies/Institute for Social Research
University of Michigan

Carlé M. Pieters
Department of Geological Sciences
Brown University

John D. Rummel
Director, Institute for Coastal Science and Policy
East Carolina University

Andrew Steele
Geophysical Laboratory
Carnegie Institution of Washington

Agency Representatives:

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

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

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

Amy Kaminski, Executive Secretary
Program Executive for Mars and Lunar Exploration
NASA Headquarters

Ms. Marian R. Norris, Management Support Specialist
Science Mission Directorate
NASA Headquarters

Appendix C
Presentations

1. Update on SMD/Planetary Science Division; *James Green*
2. Planetary Protection Office Update; *Catharine Conley*
3. The Mars Program Planning Group (MPPG); *James Garvin*
4. InSight: Science and Mission Overview; *Susan Smrekar, et al.*
5. Mars Science Laboratory: Planetary Protection Lessons Learned; *Pericles Stabekis*
6. Update on ESA Planetary Protection Activities; *Gerhard Kminek*
7. PPO Technology Studies; *Andreas Frick*
8. JPL Technology Studies; *Pat Beauchamp*
9. Joint Robotics Precursor Activity; *Victoria Friedensen*

Appendix D
Agenda

NASA Planetary Protection Subcommittee
December 19-20, 2012
NASA Headquarters 7H45 (day 1) and 9H40 (day 2)
Meeting Agenda

USA toll free conference call number 1-800-988-9533, pass code PPS
WebEx link is https://nasa.webex.com/ -- the meeting number on December 19 is 994 053 572, password PPS@Dec19; the meeting number on December 20 is 997 808 043, password PPS@Dec20.

December 19, 2012 **NASA HQ 7H45**

9:00 am	Welcome, Orientation	Amy Kaminski, NASA HQ Marian Norris, NASA/HQ
9:15 am	Words from the Chair	Eugene Levy, Rice University
9:30 am	NASA planetary exploration program plans and MSL planetary protection lessons learned update	Jim Green, NASA HQ
10:30 am	Break	
10:45 am	Update on planetary protection activities	Cassie Conley, NASA HQ
11:30 am	Discussion	E. Levy/all
12:00 pm	Lunch	
1:00 pm	Mars Program Planning Group report	Jim Garvin, NASA HQ (SMD/HEOMD)
2:00 pm	Planetary protection lessons learned	Perry Stabekis, Genex Systems
2:45 pm	Break	
3:00 pm	InSight mission	Suzanne Smrekar, JPL
3:45 pm	Discussion	E. Levy/all
5:15 pm	Adjourn for the day	

Group Dinner

December 20, 2012		**NASA HQ 9H40**
8:30 am	Overview of the Day	E. Levy / A. Kaminski
8:45 am	Update on European Space Agency planetary protection activities	Gerhard Kminek ESA
10:00 am	Break	
10:15 am	Planetary Protection Office technology studies	Andreas Frick George Washington Univ.
11:00 am	JPL technology studies	Pat Beauchamp, JPL
11:45 am	PPS members pick up lunches	
12:10 pm	Discussion over lunch in meeting room	E. Levy/all
1:00 pm	Joint Robotics Precursor Activity	Victoria Friedensen, NASA HQ
1:45 pm	Public comments	
2:00 pm	Discussion and recommendations	E. Levy/all
3:30 pm	Adjourn	