NASA ADVISORY COUNCIL

Planetary Protection Subcommittee

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NASA Headquarters
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MEETING MINUTES

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Eugene Levy, Chair

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Amy Kaminski, Executive Secretary

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May 1, 2012
Welcome and Introduction

Dr. Eugene Levy, Chair of the Planetary Protection Subcommittee (PPS), opened the meeting. New Executive Secretary Amy Kaminski, Policy Advisor for the Chief Scientist of the Science Mission Directorate (SMD) welcomed members and made some administrative announcements, also reminding members of potential conflicts of interest that may entail recusals at appropriate times.

Words from the Chair

Dr. Levy reviewed recommendations arising from the previous PPS meeting, which had been conducted at the Kennedy Space Center (KSC) in conjunction with the European Space Agency (ESA) Planetary Protection Working Group (PPWG):

- ESA and NASA should renew its Letter of Agreement, first signed in 2007, to continue joint agency cooperation in Planetary Protection activities.
- Close cooperation between NASA and ESA should be maintained through regular meetings, at least once every 2 years.
- NASA should ensure that a Lessons Learned (LL) report on the Mars Science Lander (MSL) be prepared and preserved so that future PP activities could be conducted in the light of these lessons.
- Studies should be carried forward on sample return regarding Mars satellites, particularly in the context of the Melosh report on the transfer of ejecta from Mars onto Mars satellites; this environment needs to be well understood.

Dr. Levy noted that the current meeting is taking place in a time of considerable mission and budget uncertainty for NASA, across the board, including both robotic and human space activities. The future is not clear, and the conversation is being driven by politics, budget, and technical factors. In terms of planetary protection (PP) focus, the Mars program is in a state of dislocation at present, as viewed from outside the Agency. In addition, at the prior NASA Advisory Council (NAC) meeting, Dr. Levy made note of the fact that the Science Committee communicated several other recommendations from other subcommittees directly to the NAC; one from the Planetary Science Subcommittee (PSS) to "recover the planetary exploration program," implying that the Planetary Science program is in disrepair. The SC made a similar recommendation to restore science in NASA, again recognizing that within the community, the state of the NASA science program has raised concern.

Update on SMD/Planetary Science Division

Dr. James Green, director of Planetary Science Division (PSD) of the Science Mission Directorate (SMD), presented an update. Dr. Green pointed out the tremendous successes of the PSD over recent years, which have included comet encounters and the orbital insertion of Dawn around Vesta. NASA eagerly anticipates a successful MSL landing on Mars on August 5, 2012 PDT (6 Aug EDT). The Dawn spacecraft is approaching the asteroid Ceres, having visited Vesta, and will be leaving Vesta's gravitational influence in August 2012, to arrive at Ceres in 2015. The two asteroids are very different; Ceres may have a significant amount of water. NASA will hold a press conference on the subject in late May. Rheasilvia, the largest crater relative to body size in the Solar System, was one significant discovery on Vesta. This crater has a peak 2.5 times the height of Earth's Mount Everest. The Dawn mission has also confirmed that HED (Howardites, Eucrites, Diogenites) meteorites are indeed coming from Vesta.

Elsewhere in SMD, the Deep Impact comet and MESSENGER Mercury missions are now in extended mission (EM) phases. The lunar mission GRAIL is in its primary mission; GRAIL is a two-spacecraft system studying lunar gravity, and will be producing a lunar gravity map at 35-km resolution over the three months of its prime mission. Combined with Lunar Reconnaissance Orbiter (LRO) data, GRAIL will enable future precision landings on the Moon and provide a better analysis of the Moon's structure and origin.

Three candidate Discovery missions are currently in consideration: a comet "hopper" mission (CHopper), InSIght, and TiME. Step 2 proposals for these missions arrived in March, and the down-selection is scheduled to be announced in mid-July of this year. Based on the current budget, the next Discovery Announcement of Opportunity (AO) is in Fiscal Year (FY)15. There are two upcoming launches of note in FY13: MAVEN, an aeronomy mission that will analyze the solar wind interaction with the upper atmosphere of Mars, and LADEE, a lunar mission that will have laser communications capability, marking the first major mission using this technology. Within the New Frontiers (NF) program, the New Horizons spacecraft will arrive at Pluto in July 2015, while Juno will arrive at Jupiter in 2016. OSIRIS-REx, a recently selected asteroid sample return mission, is moving for forward in its phase B study. The mission will orbit the carbonaceous asteroid 1999 RQ36 for 505 days in global mapping mode and will return 600 g of regolith sample to the Earth.

Budget

The PSD budget in the President's FY13 submission has decreased by $309M from FY12 and in the budget runout continues to decrease through the outyears. Both the House and Senate are moving to revise the PSD budget, which may restore $100-200M. Dr. Green said that this legislative response demonstrates that the both the nation and the Administration value planetary science. A major issue for continuing planetary exploration is the supply of Pu-238 supply. NASA has received Congressional approval to restart domestic production of Pu-238, which enables missions to outer planets and permanently shadowed regions on the Moon, Mars, Mercury, etc. NASA/PSD is working with the Department of Energy (DOE), which is currently conducting a study on using existing facilities to irradiate neptunium to produce Pu-238. No funds have been provided via the DOE to date. NASA anticipates having responsibility for a larger share of funding than originally anticipated. NASA will continue to develop engineering qualifying units for Advanced Stirling Radioisotope Generators (ASRGs), and is making good progress. Much ASRG work is being performed at Lockheed Martin. Dr. John Rummel commented that there are concerns with ASRG vibration, as well with the ASRG's ability to withstand heat sterilization. Dr. Catharine Conley responded that PPO is working closely with PSD on a staged approach to comply with heat sterilization requirements.

Dr. Green encouraged members to participate in upcoming celebrations of the 50th anniversary of planetary science, dated by the 1962 Mariner 2 launch to Venus. PSD is working with historians and preparing to celebrate this anniversary.

<u>Mars Exploration Program Update</u>

Mr. Doug McCuistion, director of the Mars Exploration Program (MEP), gave a status on latest Mars planning activities. All eyes at the moment are on MSL, while the Mars Odyssey orbiter is doing very well. It has been moved to all-stellar mode and is working completely from star trackers, saving fuel in the process, and preserving the lifetime of the laser in the inertial measurement unit (IMU) so that it will function at the time of the MSL landing. The Mars Reconnaissance Orbiter (MRO) has also been moved to maneuver for MSL, and ESA's Mars Express is being prepared to support MSL entry, descent and landing (EDL). The Opportunity rover has wintered over and is currently doing radio science. The MAVEN mission is also progressing very well, on budget and schedule. The mission has had only one issue with high-voltage power supplies in one instrument, and the issue has been resolved.

Mars assets continue to produce great science. MRO is producing seasonal and regional images of gullies and presumed briny water. The MSL Curiosity Rover Computer Elements are running well, no issues, while the mission is still tweaking EDL software and surface software. Landing ellipses are still being refined; the IMUs are very accurate and have greatly reduced error (ellipse is about 20 by 25 km). Curiosity will be exploring the Gale Crater over a two-year lifetime, with a 20 km range.

Moving to the next decade, the Mars program has ceased activities with ESA. At present, MEP is moving to align human exploration goals and challenges more closely with the science mission set. Launch opportunities for Mars, heavily influenced by celestial mechanics and orbital dynamics, will allow an opportunity in 2018 to get large masses to the surface. The next opportunity is 2033, followed by 2047. The first opportunity to send humans to Mars would be 2033, thus the program is trying to figure out how to work around these opportunities and budget. Technology must come along smartly as well. The Office of the Chief Technologist (OCT), SMD and the Human Explorations and Operations Mission Directorate (HEOMD) are working closely to accomplish this. The 2016 opportunity will not be possible, thus NASA would like to take advantage of 2018 and 2020. Dr. Rummel asked what could be learned between now and 2033 to allow humans to get to Mars. Mr. McCuistion clarified that the goal would be having humans travel to the vicinity of Mars, not necessarily the surface, in 2033. Dr. Rummel noted that the critical issue for humans on Mars will be radiation protection.

In order to facilitate progress, a Mars Program Planning Group (MPPG; nongovernmental) was recently formed, headed by Dr. Orlando Figueroa. MPPG will identify potential investigations, aligned with the Decadal Survey (DS).

Dr. Vicky Hipkin asked if MPPG was considering the “signs of life” pathway. Mr. McCuistion explained that there are a series of pathways that will have science as drivers but will also integrate human exploration and technology pathways. MPPG will assess orbital and lander goals, which must also take into account budget profiles and remain consistent with the President’s FY13 budget request. The Agency must also prepare for the 2014 budget. MPPG will release a final report in August, which is intended to help inform the 2014 Agency budget request. Asked where the PP aspect is being incorporated in this process, Mr. McCuistion replied that JPL has a hand in determining this, and the MPPG team itself contains the relevant expertise. PP at the mission level will be considered when the actual mission is determined. The MEPAG is not roadmapping the humans-to-Mars pathway- that is the responsibility of HEOMD. Dr. Rummel commented that if there is to be active life detection on Mars and a requirement for system-level sterilization, this will complicate humans-to-Mars planning. Mr. McCuistion noted that such measures would be necessary for the 2018 opportunity, but agreed that PP needs to be strengthened when working with design reference architectures. Dr. Levy added that the issue raises the question about PPS attachment points to the overall Mars enterprise. Mr. McCuistion noted that as missions and architectures are chosen, PP requirements must be identified for each one going forward; in that scenario, PPS may want to have a closer discussion with HEOMD. MPPG’s first task is to consider missions for 2018 and 2020, not through the 2033 opportunity. Robotic sample return is part of their thinking, remaining consistent with the DS.

Mr. McCuistion reviewed timelines and milestones for MPPG report. The National Research Council (NRC) is starting up a new Committee for Astrobiology and Planetary Science (CAPS) in the May/June timeframe. There is also a MPPG outreach website under construction. Members of the MPPG include Michelle Gates and John Shannon from HEOMD; James Garvin from the Goddard Space Flight Center, the Chief Scientist at JPL; Jack Mustard, Lisa Pratt, and Mike Gazarik from OCT. The majority of the MPPG are from NASA, but the members are actively engaging with the community. Dr. Levy felt strongly that a follow-on process for planetary protection will be critical; and that to be fair, PP representatives should be at least engaged in the output phase. Mr. McCuistion strongly agreed. Dr. Carlé

Pieters urged MPPG to consider the question of whether seeking life was actually compatible with human exploration goals: she was concerned that researchers might "discover" Earth-borne life on Mars carried by human explorers. Mr. Michael Meyer mentioned that Dr. Andrew Steele, a member of PPS, is part of the related Precursor Study Analysis Group (PSAG) and has already given considerable input to MPPG.

A Lunar and Planetary Institute (LPI) workshop will be welcoming a broad array of ideas for Mars concepts and approaches and put out a call out in challenge areas in mid-April. The call closes next week (May 10), and the workshop will take place in mid-June. Resultant ideas will feed into the architecture trade. The workshop has physical space for 200, but will also be broadcast via Webex and live stream.

Update on Planetary Protection Activities

Dr. Catharine Conley, PPO, presented an update on recent planetary protection activities, reviewing the goals of PP, particularly as they pertain to the 2012 NASA Planetary Science Goals, habitable environments, potential threats to life on Earth and in space, etc., and in terms of both forward and back contamination. The PPO reports to the SMD Associate Administrator (AA) for managing planetary protection policy. The inputs of the Planetary Protection Office and PPS apply to all of NASA.

Programmatic concerns center around an increasing number of missions that target Mars and the Outer Planets (OP). Technology development for PP, historically left to the missions, could be better coordinated to facilitate efficient use of resources. Human exploration plans present great challenges to planetary protection, and increasing interest in other space targets by private and commercial entities also raises concerns about international cooperation, commercial exploration, and historical/environmental protection. PPO resources are limited, therefore PPS recommendations are important in these areas. Thus far, interactions with commercial launch efforts seem to be working well. Mars, Europa and Enceladus are the three areas of high concern; asteroids are generally not considered regions of particular concern. In response to legal concerns, Dr. Conley agreed it would be worthwhile for NASA and PPS to regularly raise the question of launch certification issues.

PP Research

Research in planetary protection is carried out within an element of the NASA ROSES call, which solicits research that is not covered by Astrobiology (although there is some overlap in subjects and occasional co-funding). There are currently 4 grants addressing the limits of life in laboratory simulation; 2 grants in the modeling of planetary environments, 4 grants in molecular analytical methods for rapid detection of a wide spectrum of Earth microbes, and 3 grants for spacecraft sterilization. A total of $2.5M/year covers all PPO activities, with about $1.5M devoted to the research element.

Dr. Robert Lindberg asked if there was an on-ramp for academic principal investigators (PIs) allowing them to seek the next level of funding. Dr. Conley replied that there is no formal process for doing this. This is something that OCT is exploring, however, and Dr. Conley invited PPS to interact directly with OCT on this issue. Dr. Mickelson commented that in molecular studies, particularly in the medical field, there has been success in offering low-cost prizes to MIT students to deal with specific problems in synthetic biology; such a program might be useful to PP. Dr. Colleen Cavanaugh suggested that Dr. Conley visit MIT and give a talk, potentiating a valuable connection between engineers and biologists. A meeting participant noted that there is a program in OCT called Centennial Challenges, which is set up for students (and others) to compete in space science challenges. Dr. Conley noted that OCT does not appear currently to be including PP effectively in plans for future technology development for missions to locations of high concern (e.g., Mars, Europa, Enceladus). Dr. Mickelson took an action to arrange for Dr. Conley to visit MIT students.

Current and Upcoming Missions with PP Considerations to watch
Dr. Conley next described current and upcoming missions that are of concern for planetary protection and are monitored by her office.

- Dawn mission to Ceres (Ceres may contain water; the Dawn mission already has plans to address this concern)
- Two Discovery candidates- TiME and InSIGHT- a Titan mare explorer and Mars equatorial mission, respectively. These missions pose the risk of possible microbial introduction into methane lakes on Titan, and into liquid water on Mars.
- MAVEN Mars orbiter (must do an analysis on bioburden reduction)
- New Frontiers missions: New Horizons (may identify liquid water at Pluto and other Kuiper belt objects); JUNO (potential Europa jeopardy); and OSIRIS-REx (collecting samples and keeping spacecraft clean)
- MESSENGER (water ice in shadowed regions in Mercury)
- GRAIL (completing its documentation)

Dr. Rummel commented that the lack of a magnetometer on Dawn may reduce the mission's ability to detect ice/water/warm spots on Ceres.

Updates to policy and requirements
The current reconsideration and re-planning of NASA priorities allows more time to better refine PP requirements and policy development needs. Future missions will require the development of a Life Detection Protocol and sample-handling capabilities for samples returned from Mars, and implementation of PP probabilistic requirements for proposed Outer Planet mission concepts. OSIRIS-REx, e.g., can also benefit from better understanding of organic cleanliness and sample-handling capabilities. Dr. Gerhard Kminek added that guidelines from COSPAR for human exploration are also relevant, such that ESA has adopted these guidelines for the interim. Dr. Conley noted that NASA policy documents generally state that NASA will follow the Outer Space Treaty and COSPAR guidelines for human requirements. Dr. Conley took an action to distribute copies of the policy.

<u>MSL Lessons Learned and PP technology knowledge capture activities</u>

Dr. Karen Buxbaum presented a status of ongoing activities at the Jet Propulsion Laboratory (JPL) for assessing current and future capabilities in Mars PP. At its November 2011 meeting, the PP recommended to capture the extensive set of lessons learned on MSL while the MSL PP team remains intact and to preserve accumulated knowledge and experience. Dr. Buxbaum pointed out that the presentation was not to be construed as a response to the recommendation but instead as a description of activities that are synergistic with a possible response. Knowledge capture is already in motion. The recommendation is also well timed because the MSL team members are still available at JPL to support LL activities. Some are involved in short-term activities and their funding is finite.

Status of relevant knowledge capture
In dealing with issues with spacecraft materials and contamination control that may affect measurements made either *in situ* or after return, team members who are in the best position to address this topic are still actively engaged in planning. However, initial work in such areas as in developing a bioburden accounting software package, and in the publication of adenosine triphosphate (ATP) assay vs. NASA standard assay results, is being explored. Research to improve the assessments of proposed landing sites will be initiated after the landing date.

Software and ATP assay
JPL PP teams have developed and progressively enhanced user-developed, user-written software to facilitate bioburden accounting and reporting. The software suite is still modular, and is not completely documented. The tools are effective, but they are not where they should be for use by future teams, according to Dr. Buxbaum. JPL has not performed an appraisal of commercial products just yet. Dr. Cavanaugh recommended that people who write the software should assess the commercially available products, lab automation systems, etc. Dr. Lofgren noted the need for a NASA requirements document to govern the software. Dr. Buxbaum added that there is no such document yet due to the home-grown nature of the user tools that had been designed for a specific task. Dr. Conley noted that such documentation is being undertaken at Goddard Space Flight Center. The real challenge is in understanding the match-up between plate counts and pieces of hardware. Dr. Buxbaum reported that at present, there is a small, $15K three-week effort to capture the necessary information.

From 2001 to 2005, the Mars program supported development of two molecular assays to expand and update bioburden assessments of spacecraft surfaces; these were total ATP assays vs. limulus amoebocyte lysate (LAL) assays. MSL made extensive use of the ATP assay to rapidly assess cleanliness surfaces during the pre-launch period, to mitigate the risk of any rework of three-day spore assays. The data collected is not yet consolidated and fully documented. The PPS recommendation included a call for data analysis, thus Dr. Buxbaum has initiated a task to consolidate the data into an Excel and back the data up to allow future analysis. This four-week task is in process.

The Mars PP budget includes resources to start knowledge capture activity that would be valuable to future missions, and to prevent the loss of approximately 15 years of PP-related research and development. Some of the individuals involved in this research are nearing retirement or are coming to the end of their funding, thus capturing these lessons is time-critical. The Mars program shares the PPS/NAC concerns about the potential loss of knowledge and expertise. Dr. Levy commented that the main message from PPS is that this is an urgent issue. Dr. Buxbaum agreed, adding that if a full response to the PPS recommendation exceeds the budget or authority to initiate new work, the Mars program would need a recommendation that explicitly addresses funding.

Dr. Mickelson asked if any samples had been archived. Dr. Buxbaum responded that the samples are perishable, and the funding for a DNA and microbial archive is not particularly large but it is continuous. Dr. Buxbaum reported having funded a small study to assess a microbial archive, which led to a pilot study that involved MSL cultures from petri dishes. This activity gave rise to a larger three-year project supported by NASA for its relevance to PP and astrobiology, and to characterize additional sets from Viking, MER, Phoenix, etc. New splits and lyophilized stocks have been made as a result of the project. There has also been discussion of creating a PP archive. Dr. Mickelson commented there has been much progress in forensics that can help to enrich for extremely rare nucleic acids (culture-less). Dr. Conley noted that NASA is already doing environmental genomics in clean rooms and also has ties with forensics science that is being conducted by the National Biodefense Analysis and Countermeasures Center in the Department of Homeland Security. Dr. Buxbaum added that JPL has long been conducting studies to extract a sample from an extremely small amount of biomass to produce a clean, amplifiable amount of DNA. JPL is in the process of finishing, documenting and publishing this latter activity.

Strategic Knowledge Gaps (SKGs): Planning for Safe Effective and Efficient Human Exploration of the Solar System

Dr. Michael Wargo, Chief Exploration Scientist for the Human Exploration and Operations Mission Directorate (HEOMD), presented a briefing on HEOMD work that is focused on identifying strategic knowledge gaps (SKGs) that will need to be filled to enable human exploration to go forward. According to Dr. Wargo, science enables exploration and exploration enables science, as opposed to the historical divide between science and human exploration missions. Planetary science, for example, knows how to make measurements that are important to human exploration. Dr. Wargo said the Lunar Reconnaissance Orbiter (LRO) mission is the poster child for how to do this right, and the Decadal Survey has called this mission out as an exemplar.

NASA has recently created the Joint Robotic Precursor Activities (JRPA), an effort between the Advanced Exploration Systems Division within HEOMD and the PSD of the SMD. A small R&A effort will be supported to turn the data gathered by JRPA instruments into strategic knowledge. A number of these studies will be conducted to maximize the mutual benefit to both science and exploration objectives, as was successfully shown with LRO. JRPA will also maintain a small study effort to plan for future precursor activities.

To inform mission/system planning and design, and near-term Agency investments, Human Spaceflight Architecture team (HAT) destination leads were asked to identify the information needed to reduce risk, increase effectiveness and aid in planning and design. For some destinations, the necessary knowledge is well defined; analysis groups such as the MEPAG and the Lunar Exploration Analysis Group (LEAG) have identified pertinent investigations and measurements needed for Mars and the Moon; significant advances in filling knowledge gaps have been made through missions such as LRO and MRO. NASA will therefore be able to establish traceability of the SKGs to its currently planned robotic missions, the International Space Station (ISS), R&A, and exploitation of ground-based assets. The concept of the SKG has expanded beyond NASA and into international space efforts.

Dr. Pieters asked if human activities at particular destinations have been defined. Dr. Wargo responded that these definitions existed at a high level. At present, SKGs are in draft form, however, and they must be further vetted. Dr. Pieters worried that "getting there" is the principal objective of HEOMD. Dr. Wargo noted that to support science, NASA is in the process of engaging the external science and exploration communities to vet and refine the SKGs. LEAG's assessment is complete, the Small Bodies Analysis Group (SBAG) should have an interim product shortly, and the MEPAG has produced a draft result. The lunar team was trying to establish a variety of pathways, such as science and feed-forward to Mars pathways, and how to do things sustainably. The latter pathway was chosen for the lunar effort. For Mars, MEPAG's Goal 4 (see MEPAG website: mepag.nasa.gov) was chosen; which would then be assessed, with a small change, for its value for human exploration.

Common themes for human exploration are radiation, regolith and reliability. Other themes are geotechnical properties, volatiles, propulsion-induced ejecta, *in situ* resource utilization (ISRU), operations/operability, plasma environment, and human health and performance. For some observations, the required information is measurable and attainable; the measurements do not require exquisite science instruments but could be obtained from them. Filling the SKGs requires a well-balanced research portfolio that includes remote sensing and *in-situ* measurements, ground-based assets, and R&A, as well as science, technology and operational experience. Dr. Pieters observed that several important NASA programs have had gaps due to discontinuity. Dr. Wargo replied that one of the principles of the program is based on maintaining an ongoing effort. Dr. Pieters asked how follow-on studies at HEOMD will bridge activities to SMD. Dr. Wargo explained that when JRPA gets past the draft stage, HEOMD will look both at NASA and internationally for a good opportunity. PPS will have great relevance in assessing the goals of the Mars SKG activity. PSAG must weigh in on this as well.

<u>Update on OCT activities- Space Technology Program</u>

Dr. Prasun Desai gave an overview of OCT activities. The Office of the Chief Technologist (OCT) serves as an advisor to the Administrator, integrates technology investment across the agency, directs technology management and budget authority for the Space Technology Program, leads technology transfer, partnerships and commercialization activities across the agency, advocates externally for NASA's research and development programs, and demonstrates and communicates the societal impacts of NASA technology investments. OCT also assesses national needs (e.g., launch vehicles) as well as NASA needs. OCT takes input from mission directorates, external technical partnerships with DOD, NOAA, DARPA, etc., and the Strategic Space Technology Investment Plan. Guiding principles of OCT are informed by strategic guidance documents from various sources and roadmaps. OCT is structured to govern the full spectrum of technology programs, described as pursuing "step-function" progress in advanced technology. OCT conducts competitive and peer-reviewed selections, and follows a projectized approach to "cross-cutting" technology development (useful for multiple customers); the overarching goal is to re-position NASA on the cutting edge. OCT will define start and end dates for projects to conserve resources, take informed risks, seek disruptive innovation, and foster the emerging commercial space industry (specifically suborbital platforms). Under OCT there are ten programs in Space Technology, including low-TRL areas, Center Innovation Fund Program, Centennial Challenges Prize Program, SBIR/STTR programs, game-changing technology at the TRL 3-5 levels, and technology capability demonstrations in the higher TRL categories, such as the Edison Small Satellite Demonstration program.

NASA's Space Technology portfolio utilizes space technology roadmaps (20-year time horizon), NRC studies (5-year time horizon), a Space Technology Investment Plan (immediate 4-year horizon), and an Execution strategy (technology developments and flight demonstrations). OCT has not ruled out international cooperation. There are 14 technology areas, including launch/propulsion systems, communication and navigation, and thermal management systems. In the NRC Report on NASA's Space Technology Roadmaps, the subject of planetary protection was considered and highlighted in robotics, human health systems, thermal management systems, and EDL. However, OCT does not specifically call out specific PP technologies in which to invest, but does recognize PP as an integrated process. The NRC has identified three highly relevant technology objectives: extend and sustain human activities beyond low-Earth orbit (LEO), explore the evolution of the Solar System and potential for life elsewhere (*in-situ* measurements), and expand understanding of the Earth and the Universe (remote sensing). Dr. Peter Doran asked if bio-isolation was called out in these objectives. Dr. Desai replied that this was not considered as a specific technology but was identified as part of the mission design process. Dr. Rummel noted that contamination control within a habitat on Mars would be a huge problem; a habitat would require a grit-proof, extremely clean airlock system to avoid perchlorate inhalation; such technology deals with filters and ugly problems that people don't like to think about. Dr. Lindberg felt that PP did not seem to be a high-priority for NRC and expressed concern that it was not specifically called out in the roadmap. Dr. Lofgren noted that NASA is working diligently on airlock technologies, and that OCT is studying specific back-contamination and re-entry survival problems that are relevant to PP and sample return.

The NIAC program currently has a solicitation for proposals (open topic areas), and STTR/SBIR subtopic areas can be further defined for PP technology. The PPS may also choose to recommend a program focusing on the maturation of promising cross-cutting technologies for PP. Dr. Conley mentioned that there had been a Small Business Innovative Research (SBIR) focus area for PP in the past. Dr. Buxbaum added that starting in 1999, NASA has had a fairly good selection rate for SBIR; however, any required program relevance to planetary protection needs to written very specifically into the call. Very few of these selections have led to phase 3 activities. Dr. Rummel pointed out some serious omissions in the NRC document that limits PP coverage and technology development and suggested the PPS develop a recommendation specific enough to support the necessary technology investment for PP.

<u>Discussion with SMD AA</u>

SMD Associate Administrator (AA) Dr. John Grunsfeld addressed the PPS, first thanking members for their service. He also cautioned members to be mindful of their public commentary, lest it be misconstrued, especially in terms of PPS advice to NASA. He expressed a thorough consideration for both forward and backward contamination in terms of both astronaut corps and scientific expertise, and expressed a desire to see a compelling narrative for exploration, to answer the question of whether we are alone in the universe, while regarding PP as a relatively near-term consideration. He said that he viewed PP as not an obstacle to but an enabler of space exploration, with its focus on communicating risks, managing expectations, and development of needed technologies. He noted that both Dr. Green and Dr. Steve Squyres, Chair of the NAC Science Committee, support Mars sample return in advance of human exploration of Mars. Dr. Steele commented that the concepts of biohazard, life detection and planetary protection are all the same, a philosophy that needs to be understood. Dr. Rummel added that NASA must consider how to quarantine an astronaut, prevent exposure to pathogens, etc., which will require the integration of human health monitoring and PP to safeguard such missions. Dr. Levy commented that public perception and science data need to be reconciled. Dr. Jere Lipps raised the question of the effects of space flight on the immune system. Dr. Grunsfeld commented that while one might expect the contrary, astronauts appear to have significantly better health in space than on the ground. Astronauts also tend not to get sick when they get return to Earth. Resistive/aerobic exercise also seems to help (specifically with regard to flights on ISS). A six-month cruise on ISS might be regarded as roughly equivalent to a cruise to Mars, save for radiation and psychological issues.

Dr. Rummel commented that NASA must ensure that astronauts can return from a space mission without ambiguity. Dr. Mickelson noted that one must also take into account the fact that pathogens attenuate as they propagate through living systems; that is knowledge that also should be disseminated. NASA should not play into fears, given that there is epidemiological knowledge that can be utilized and communicated to the public. One should be able to show that NASA is taking reasonable, defensible steps to prevent contamination, and that microbes are a necessary part of the human microbiome. The subcommittee discussed the preservation of Earth in the context of the future preservation of Mars. Dr. Steele commented that NASA needs to lead by example to minimize the disruption of Mars via exploration efforts.

Dr. Levy highlighted a particular concern held by PPS as a committee, which is the intensity of NASA's efforts to reach Mars has prevented the incorporation of sufficient planetary protection measures. Dr. Grunsfeld asked the committee for helpful, actionable recommendations in order to address the concern. He also suggested the public might be able to offer potential solutions, through prizes or other mechanisms. Dr. Buxbaum noted that some of the PP challenges may require a body of scientific research in biology problems or engineering technology that lack a natural home in NASA/OCT. Dr. Grunsfeld felt that some of these subjects might fall in under Astrobiology, or R&A, or in procedures. Dr. Rummel commented that PPS advice did not go up to the higher levels of the NAC due to certain personal sensitivities. Dr. Levy encouraged PPS to pursue closer ties with HEOMD. Dr. Grunsfeld concluded the discussion by encouraging PPS to participate in the LPI efforts to undergird future Mars exploration.

Overview and Summary of a Life Detection Protocol Update Workshop

Dr. Conley presented an overview on recent efforts in improving the efficacy of handling sample returns. In order to develop a life detection protocol, NASA and ESA held a public conference to encourage discussion and develop a consensus on what is required for a credible claim for life detection. A by-invitation workshop was then held to address measurements needed to answer broader scientific questions to be used also for planetary protection purposes, focusing on minimizing use of scarce samples and avoiding duplication of effort. The workshop objectives included evaluation of current and possible investigations that could identify life in samples returned from Mars; assessment of the available technologies and identification of areas that needed future work; a discussion of phasing sample analysis for planetary protection and science interests; and identification of needed improvements in sample preparation, detection technology, and controls that would increase confidence in results. The conference focused on assessing the potential contributions of different kinds of measurements and coordinating scientific and PP interests. While there were some papers on detecting life *in situ*, the focus was on sample return. Dr. Pieters asked what requirements might be necessary for assessing probabilities of life detection; i.e. what risk is officially acceptable? Dr. Baecher commented that there is no approach for dealing with total 'sterilization' on Earth; statistics can't provide adequate answers to this question.

Inputs from the conference included a set of assumptions: life to be based on carbon chemistry (water-soluble chemical reactions) at Mars-surface pressures and temperatures, and on human-detectable timescales. Important features would include determination of the structure and morphology, chemical composition and heterogeneity of samples, and the environmental and thermodynamic context of samples. Two hypotheses should be tested: there is no life in samples vs. there is Mars life in the samples. Data collected could be interpreted in the following ways: providing strong biosignatures, indicators of abiotic processes, or indicators of Earth contamination. It is currently thought that globally, Mars appears to be in equilibrium, another assumption that might guide the interpretation of a sample.

Samples would be considered in terms of possessing the properties of living systems - order, replication, growth and development, energy use, response to environment, etc. The workshop also considered a framework dealing with back contamination in a candidate Mars sample-handling scenario, including a sample return protocol. There was a brief discussion of the implications of PI-led investigations vs. planetary protection measures in the finding of life, as any protocols would be inextricably tied with a sample-handling facility.

The workshop identified some general principles governing the search for life, beginning with a broad survey of the sample portion, emphasizing the structural signatures of life and other inhomogeneities, and emphasizing less destructive methods initially, starting with samples that are least likely to contain life. Some methods might include computed tomography, elemental imaging, and mineralogical analysis. Subsample processing could include remote manipulation. Targeted characterization might include prepared surface imaging, microscale probes, and particle analysis.

The workshop dealt with specific questions in breakout sessions. Breakout Session 1 questions included how to detect signs of life in samples from an environment, assuming no prior knowledge of local life; what measurements might be made; how to deal with sample heterogeneity; and what commonalities of life could inform the detection process. Breakout Session 2 dealt with designing a life detection protocol, which took into account potentially useful macro-scale and micro-scale measurements that could distinguish between Mars life and Earth contamination. The full discussion included use of Bayesian approaches to data.

Conclusions of the workshop were that testing competing "null" hypotheses provides an effective strategy to address both PP and scientific interests. Sample handling and containment are key technology needs; significant improvements in clean, subsampling capabilities are needed. Remote micromanipulation could greatly facilitate clean sample handling. Some suggest using current samples that contain no life, or contaminated samples, to test out the approach. Dr. Lofgren noted that NASA possesses a lunar sample that has been never been opened. Several types of assays were discussed, including various forms of spectroscopy (Raman etc.) and nanoSIMS techniques. Dr. Steele commented that each technique should have a similar decision tree for both life detection and PP, representing a cumulative decision based on many techniques and measurements, preserving as much sample as possible. Samples must also stay in containment to the equivalent to BSL-4 level. Samples are completely isolated from humans as well, to prevent forward or back contamination of investigators/sample. The workshop concluded that considerable obstacles remain in instrumentation in terms of both cost and means of containing samples. Dr. Michel Viso pointed out that some techniques have consequences for curation in the downstream measurement timeline, thus sample pristineness is of top priority. Dr. Mickelson added that one would need a core competence of people who are comfortable working at the BSL-4 level, which can be extremely cumbersome. Such a working corps could work at the direction of visiting scientists. Dr.

Conley agreed that the constraints of the handling facility had been recognized as an issue. PPS concurred that any downstream decisions should be made in forums where ideas are freely discussed.

Result of European Science Foundation (ESF) Study Background and Draft Conclusions

Dr. Kminek reviewed Mars Sample Return (MSR) COSPAR policy and requirements. MSR continues to be categorized as "restricted Earth return." Any sample must reside in a closed canister, and there must be a method to "break the chain of contact" with Mars. Advice from latest US/NRC (2009) report on sample return is similar. However, these criteria are not sufficient to design and test a flight system. A qualitative or quantitative approach must be defined, after which requirements must be derived for developing engineering solutions, etc. A draft requirement from an earlier (2000) report stated that the probability that a single unsterilized particle of 0.2 micron or greater is released in the terrestrial biosphere shall be less than one in one million. The most recent ESF task was to review the draft requirement and recommend a level of assurance for preventing an unintended release of a potential Martian life form into the terrestrial biosphere, not including any consequence analysis.

Dr. Kminek presented some draft conclusions. The ESF Study Group concurs with the approach adopted in the past and agrees that particle size is an appropriate constraint, but that the 0.2 micron value is no longer appropriate, as it excludes viruses, gene-transfer agents, etc. A new constraint of 0.01 micron should now be considered acceptable, and that any release of particles larger than 0.05 micron is not to be considered acceptable. (Dr. Kminek noted that he has requested a clarification concerning the particle size discrepancy). It is crucial to understand that for an MSR mission, the required level of assurance for not releasing a particle is not the same as the level of assurance for not contaminating the Earth. A Sterility Assurance Level (SAL) is an example that can be used to illustrate this concept, i.e. dealing with assurance levels but not potential consequences. Dr. Buxbaum asked if these requirements dealt with implementation, and in the sensing of particle loss- is this what influenced choice of particle size? Dr. Kminek stated that the ESF group was familiar with these issues and had the relevant expertise in the team. One of the critical issues identified already in previous studies on the JPL side is to correlate the particle size requirement with the efficiency of seals, which are usually tested with respect to leak rates..

The ESF report should be final by the end of May and will be transmitted to PPS for comment. There will be a discussion of the report with the ESA PPWG at end of May as well. The ESF report will be presented at the COSPAR General Assembly in July 2012. Thereafter, planning will discuss detailed formulation of Agency-level requirements between ESA and NASA for implementation at the industrial contact level. Dr. Viso commented that the seal introduces the potential for some pollution; one might need soldering to seal a sample container, ideally. Dr. Baecher noted that the rate of human error in multiple-step operations is about 10^{-3}. The 10^{-6} value must take the human error variable into account. Dr. Lindberg recommended that ESA consult NASA's Office of the Chief Engineer (OCE). Dr. Conley added that the Cassini mission has very good control in terms of this error rate. Dr. Kminek agreed, mentioning that ESA has had parallel industrial studies on return vehicles, and that these (reliability) numbers are familiar for human-rated space systems and civil aviation, and that there is an identified need to feed this kind of expertise into the development of robotic systems.

Discussion

PPS discussed some incipient recommendation ideas, such as recommending that Dr. Conley join the MPPG, or writing a letter to Dr. Grunsfeld expressing concern that planetary protection is not adequately represented at MPPG. Ms. Kaminski noted that a PPS recommendation on this matter would come too late to affect the MPPG process and that the PPO's involvement should be addressed through other channels. Dr. Rummel commented that the NRC has not addressed PP for human missions because "NASA has no policy;" but that assumption is wrong, and it is probably time to develop an NASA Policy

Requirements (NPR) document to complement the parallel robotic document with basic guidelines for human approaches. Ideally such an NPR could be signed by both SMD and HEOMD. Dr. Kminek noted that the general technology research program in ESA is developing a generic break-up/burn-up technology for Mars and offered to present the particulars at a future meeting. Dr. Lindberg concurred, adding that this might be an opportunity for co-investment. Other recommendation ideas included specific support for developing a life detection protocol. Dr. Conley took an action to send a list of high-priority items to PPS. Dr. Perry Stabekis suggested advocating for a larger PP budget to pursue some items that do not fall under OCT purview.

<u>May 2, 2012</u>

Ms. Kaminski opened the morning session.

<u>Ethics Briefing</u>
The PPS received an annual ethics briefing from James Reistrup, including new information on the new Stop Trading on Congressional Knowledge Act.

<u>Planetary Protection of Hayabusa 2 Mission</u>

Dr. Hajime Yano presented a courtesy briefing on the Japanese Space Agency (JAXA) near-Earth object (NEO) asteroid sample return mission, to be obtained from the near-Earth Object (NEO) 1999 JU3. Dr. Yano expressed gratitude to the international partners and reported that the mission would be seeking PP resolution from the COSPAR meeting in July.

Dr. Yano briefly described Hayabusa 1 as a demonstration mission; using lessons learned from the first mission, JAXA planned Hayabusa 2. A third mission is planned for the 2020s to visit other NEOs and asteroids. Hayabusa 1 visited the S-type asteroid Itokawa and successfully obtained a sample; Hayabusa 2 will visit a C-type asteroid, which comprises the main type in the asteroid belt. A December 2014 launch is planned, with a 3-year cruise to arrive at the target, where the spacecraft will spend up to 18 months to complete a global mapping effort and perform multiple sampling attempts as well as the landing of multiple landers/rovers. An impactor will be developed to a form crater from which to collect ejecta. The mission will depart the asteroid in 2019 and return to Earth in 2020.

The primary goals of Hayabusa 2 are to investigate origins, develop technologies for Solar System exploration, and extend the reach of human exploration as well as to more specifically determine characteristics of a C-type asteroid. The mission has a wet mass of 600 kg and is highly similar to Hayabusa 1 in terms of payloads: multiband imager, near-IR spectrometer, thermal IR imager, laser altimeter (LIDAR), a small carry-on impactor, separation cameras, small JAXA rovers, and a small rover (MASCOT) from the German space agency (DLR). The mission plan is to collect several 100-mg samples of regolithic and monolithic fragments. Sample collection techniques are heritage from Hayabusa 1. As with the first mission, Hayabusa 2 will collect data on physical property measurements (temperature, elasticity, etc.). Dr. Steele raised a question about the powder cartridge device used in the impactor: how it works, what kind of gunpowder, and how to avoid contamination? Dr. Hajime said the impactor is a bullet fired by a piston (the piston is accelerated by the gunpowder); the device itself will be sealed such that the gunpowder remains inside the gun. The projectile will be jettisoned without contamination. Asked about evidence of contamination during the Hayabusa 1 mission, Dr. Hajime reported none.

The landing of the Hayabusa 2 capsule will take place in Woomera, Australia. Samples will be examined at the curation facility built for the Itokawa sample, in an inert gas environment or vacuum. The target asteroid is 922 m in diameter, just inside the orbit of the Earth, with an orbit inclination of about 6 degrees. Ground observations indicate that the object has a more rounded shape than Itokawa, and a 7.6-hour rotation rate, with an albedo of 0.037. The spectral type in optical and near-IR is a smooth-textured, C-type asteroid, with a SMASS classification given for the absence of a particular absorption feature. Surface dichotomy expected based on ground observations include some weathered areas and a pole orientation of two possibilities: retrograde, or pro-grade but highly inclined.

The mission has considered the six questions underlying planetary protection classifications, and for the outbound phase, Hayabusa 2 is considered category II. Inbound is category V; the question is should the return be restricted or unrestricted? C-type asteroids fall under the Ib category (lesser degree of confidence). Parameters relevant for judging for presence of biological entity were considered, including the presence of liquid water, etc. JAXA used the application of the most recent knowledge of carbonaceous chondrites and associated C-type asteroids. There is spectral evidence of minerals, water and organics on some C-type asteroids. The presence of liquid water is uncertain. There is no evidence of metabolically useful energy sources, nor is there evidence of sufficient organic matter (CO2, carbonates, or reducing equivalents). The body has not been subjected to extreme temperatures in terms of most of its most materials, but perhaps in local heat maximums such as impact craters. There is sufficient radiation exposure for sterilization of terrestrial life forms. There is evidence that an equivalent sample return in the form of meteorites has returned to Earth, leading to the establishment of a category V "unrestricted" classification for sample return. Dr. Yano welcomed all inputs from PPS and expressed his wish to continue a good collaboration with NASA, as had been done with Hayabusa 1.

Dr. Rummel emphasized that Hayabusa 2 would not require a formal resolution through COSPAR for the purposes of recommendations to the Australian government; the Alpbach discussion is the most important part for Australia. NASA can write a letter recommending that the Alpbach presentation use the questions as formulated by COSPAR, and represent agreement with all the points presented as in this briefing. JAXA has already informed the colloquium. Prof. Gabrynowicz asked about the level of previous negotiations with Australia for Hayabusa 1. Dr. Rummel explained that the government was represented by Environment Australia (equivalent to the US EPA) and an animal health organization (Biosecurity Australia), which both agreed with COSPAR/NASA guidance. In the case of a crash, JAXA was required to excavate around the impact site. Dr. Rummel moved to accept the JAXA classification of the asteroid as C-type, and concurred with the classification as category V, unrestricted Earth return. The PPS responded with a unanimous agreement. Dr. Yano requested minutes of the PPS meeting for future reference.

OSIRIS-REx asteroid sample return mission

Dr. Jason Dworkin, Project Scientist, presented an update on the progress of mission planning. The OSIRIS-REx asteroid sample return mission is a PI-led New Frontiers mission, designed to return 60 g or as much as 2 kg of sample from a carbonaceous asteroid, representing a significant amount of ancient pristine material from the early Solar System, to explore the asteroid-comet continuum (main belt, class B asteroid), and catalyze the emerging integration of remote sensing and sample analysis. To date the only carbonaceous asteroid previously visited is Mathilde; the NEAR spacecraft flew by this asteroid in 1997. OSIRIS-REx chose its target, RQ36, because it is a large-diameter, slowly-spinning object with the desired carbonaceous material, and has been well characterized by both ground- and space-based assets. The target is a volatile-rich asteroid, with low albedo (3%) that is expected to provide exciting science. Its shape, size and rotation rate are very well known, and it is also among the most hazardous known NEOs, with a potential for impacting Earth in the 22nd century. The motivation for sample return from this object is that most analytical instruments for understanding mineralogy, petrology, elements and isotopes, etc., cannot be flown.

Everything on the spacecraft supports sample return; the device for sample collection device resembles a car filter, and blows N gas to collect material. The mission also plans to return a surface sample to examine weathering, using a steel Velcro or reticulated aluminum foam material, which needs to be compliant with sterilization techniques. The mission will be using a heritage return capsule. Mission planners would like to obtain PPS advice on how to best preserve samples for future study, and to ensure that any preserved samples avoid biocontamination.

The mission seeks to control contamination by returning the sample under vacuum, using dry heat to remove contamination from the spacecraft, and examining monolayer levels of organics.

Using Lessons Learned from Stardust, the mission planners have noted that the use of Synlube as an unmolding agent for the aerogel introduced some uncertainty into the Stardust mission. The new mission is therefore taking extra care to characterize and archive its techniques. OSIRIS-Rex will employ the same planetary protection categories as Hayabusa 2. The mission will develop a global map and perform radio science, and will include a student collaboration experiment on an x-ray analysis of regolith. The mission will also perform mapping to understand texture and morphology for a sample site, and measure the Yarkovsky (non-Newtonian) effect on potentially hazardous asteroids. Data collected will be compared also to ground-based measurements for correlation. The mission is now in phase B, with a launch date scheduled for 2016; the spacecraft will linger at the asteroid for approximately 500 days. There will be enough resources on board to sample the asteroid three times.

Asked about sealing procedures, Dr. Dworkin reported that the mission would employ a tortuous-path seal as used in the Stardust mission, and an air filter that allows pressurization and depressurization. The sample will ultimately be exposed to atmosphere. In analog studies, the mission planners have obtained 120 g under worst-case conditions, using rock-based simulants. With lighter simulants, a kilogram has been obtained. Based on thermal inertia, mission planners believe there is centimeter to sub-centimeter-sized regolith. Dr. Lipps felt that sample mixing, in the case of multiple sampling, would not be ideal. Dr. Dworkin noted that it would be cost-prohibitive to artificially separate the samples.

The spacecraft will use imagery and spectroscopy to confirm that the sample site contains loose regolith. There is no requirement to sample the surface (but it is a scientific desire). The mission requirement would be to successfully obtain one sample. The largest single pebble size would be 2 cm. The landing ellipse is 25 m at present, but still being actively studied. The cleaning approach and verification techniques include active work on developing wipes and rinses, based on NRC guidelines; 100 a/2 contamination, standard industrial techniques, witness plates, and rapid amino acid analysis. The mission will employ contamination knowledge coupled with contamination avoidance. Dr. Steele asked if a minimum signal has been identified for surveying the target area. Dr. Dworkin responded that if the area resembles Murchison, there will be no issues. If indications show that it is more like a CM1 meteorite, a more conservative approach will be used. The cost of the mission is estimated at roughly $1B. Dr. Pieters asked how the potential identification of the object as an extinct comet nucleus would affect an Earth return categorization. Dr. Conley noted that PPS has already weighed in on this mission as an unrestricted Earth return. The category will be revisited if necessary. Dr. Dworkin assured the committee that he would be signing off on all manufacturing processes.

<u>SSB Solar System Icy Bodies</u>

Dr. Geoffrey Collins presented an NRC report, commissioned by SMD in 2010, which aimed to expand the understanding and assessment for the potential of contamination at Europa and other icy bodies via introduction of a viable organism into liquid water. The report, *Assessment of Planetary Protection Requirements for Spacecraft Missions to Icy Solar System Bodies*, is based on the contributions of members with broad areas of expertise in biology, planetary and geosciences, and technical services. The charge to the committee was to consider factors such as the Coleman-Sagan formulation that described the probability that various missions might contaminate liquid water, to look at conservative values for risk factors, and to describe possible suitable missions. The report was approved for release and NASA was briefed on its contents in April 2012.

Major recommendations of the report are that planetary protection measures should not continue to rely on the Coleman-Sagan formulation, and that PP decisions should not rely on multiplication of probability factors. The formulation should be replaced with a series of binary (yes/no) decisions that consider one factor at a time to determine the necessary level of planetary protection. The committee also found that there is no sound basis for a recommendation of 10,000 years or more for a period of protection, as it is impossible to estimate the timeframe of exploration of the Solar System. The report recommends therefore that a period of protection should extend for a millennium.

The report committee received briefings on the geology of icy bodies, biological sciences (psychrophiles, radiation resistance of living systems), etc. Dr. Collins briefly reviewed the Coleman Sagan formulation, which states that the result of various probability multipliers should yield a probability of 10^{-4} or less of contamination. He noted the NRC's Europa 2000 report used a slightly more detailed Coleman-Sagan formulation. Dr. Rummel noted that the current formulation used by NASA was not in fact the Coleman-Sagan formulation; the Europa 2000 report was accepted only as a broad outline by both COSPAR and NASA.

The NRC report concluded that current knowledge does not confidently assign values within a factor of 10, and not all bioload reduction factors are independent. The problem is that the probability of contamination is not an actionable result. Dr. Collins provided an analogous problem: he said that if the Coleman-Sagan formulation had been used to determine how many lifeboats were needed on the Titanic, the result would have been 1.12 lifeboats. The calculation does not prove itself useful for prevention of a single catastrophic event (such as contamination of a planet). The report recommended therefore to abandon multiplying bioload estimates and to instead answer, qualitatively, two questions: Is there a non-negligible probability that terrestrial microbes would survive entry into planet? And, is there a probability that they could survive? In this context, NRC recommends using a series of binary decision trees that consider one factor at a time to determine the appropriate level of planetary protection procedures, considering at base the probability of a spacecraft coming into contact with a habitable environment.

Decision point 1 was based on a survey of icy bodies to delineate areas of concern for the existence for potentially habitable bodies within the last hundred million years; this eliminates many icy bodies from concern. It has been concluded, for instance, that no significant liquid water exists on small irregularly shaped bodies. Thus the first decision point queries for the existence of liquid water at a destination. Decision point 2 concerns key elements and their bioavailability that would putatively support the survival of a terrestrial microorganism. Decision point 3 assesses physical constraints on support for known extremophiles. Decision point 4 considers whether current data indicate that minimal chemical energy sources (CO2, electron donors and acceptors, e.g.) exist at the target destination. Decision point 5 considers the probability that a spacecraft is likely to contact a habitable environment (10^{-4}) in 10^{3} years. Decision point 6 considers the presence or absence of complex and heterogeneous organic nutrients that might support life in aqueous environments on icy moons/bodies. Decision point 7 determines the conditions necessary for minimal planetary protection measures (60°C heat treatment for 5 hours), versus the most stringent (Viking-level, terminal bioload specifications for sterilization). As to decision point 7, the report concluded that this area would benefit from more intensive study, particularly of organisms that grow and proliferate at low temperatures. The current conclusion is that spores from psychrophilic bacteria are likely to be rendered inactive at temps above 40°C.

Dr. Collins presented a few examples of how a binary decision tree would classify a comet lander mission, or an Enceladus geyser surface lander, or a Jupiter orbiter (presenting a danger to Europa).

The report recommends reliance on molecular-based assays as well as continued research into methods and conditions required for heat inactivation of spores, understanding conditions for spore formation, and searching for more psychrophilic spore-formers, looking at protected microenvironments within the spacecraft itself and the formation of biofilms that could resist heat treatment. Also recommended is the development of technologies to directly detect and count viable microorganisms on spacecraft. More research is needed to determine key elements on icy bodies, and we need to better understand surface and subsurface transport of materials on icy bodies.

Dr. Rummel felt that decision point 5 should be the primary decision point, particularly as other decision points could not be assessed with a necessary degree of confidence. Dr. Baecher noted that liquid water is always a probability and not subject to a yes/no answer. There was a fair amount of disagreement within PPS regarding NRC's assessment of probabilities, based on the current data, as well as extensive debate on assumptions made about ice, survival of organisms such as *E. coli* in certain extreme environments, the existence of shallow lakes on Europa, and a vertical-transport, worst-case scenario of fractures on an icy shell that could provide a direct conduit from the subsurface to the surface.

Dr. Steele noted the difficulty of assigning limits to life parameters. Regarding decision point 6, for example, data on radiation effects and availability of nutrients are generally not available for icy bodies. A new, unexpectedly simple method of radiation resistance (iodine-chloride pump) has just recently been observed in microorganisms. There is no expectation to rule out even more novel mechanism discoveries in the future. Dr. Lipps pointed out the difficulty of making any type of prediction for a heterogeneous body like Europa, for which the physical properties are known. Dr. Collins acknowledged that there is no blanket answer for all missions. Dr. Rummel cited Jupiter Icy Moons Explorer, ESA's next mission, which is planning 2 flybys of Europa, with a plan to measure its crustal thickness; PP decisions for this mission must be made without critical data.

<u>Public comment period</u>

Dr. Bob Pappalardo asked how the NRC report would be assimilated into NASA planning. Dr. Conley responded that many valid concerns will be addressed, and there will be a presentation of the report at COSPAR as well. Useful areas of the report will be adopted, and it may be further analyzed and further refined, including further input from PPS. It is the policy at NASA level to look long and carefully at approaches that increase the difficulty of a mission. Dr. Conley did not anticipate any decisions coming forward to the COSPAR panel in July.

<u>Discussion</u>

PPS discussed its concerns about probabilities, engineering implications, and biological data emerging from the NRC report. Prof. Gabrynowicz felt the decision trees represented false dichotomies. Dr. Mickelson noted that confidence levels are not clarified; this would be possible if the state of knowledge were clearer, but this is not the case. Dr. Lindberg regarded as useful the criticism that some values used to assess PP measures are not in fact independent. Dr. Baecher felt that PP questions are epistemic in their uncertainty characteristics, and that Bayesian techniques would be needed to answer some of these questions.

Dr. Kminek had understood as the primary expectation of SMD that the NRC study would provide more information about the individual parameters used in the reduction factors approach. The charter of the study explicitly addressed the matter within the context of current COSPAR guidelines. PPS could not confidently find merit, for example, in the report's suggestions for eradicating psychrophiles, as most research in this area takes place under laboratory conditions; it would be more useful in this case to obtain data in the field. The report has been delivered to NASA in draft form. NASA has already had discussions about the "unknown" response to the decision tree format and is awaiting advice from PPS on which aspects of the report are useful. Dr. Rummel recused himself from this part of the discussion. Dr. Levy asked all members of committee to communicate concerns in writing, within a week or so, as an informal communication.

PPS discussed forwarding a recommendation on creating a policy and procedural requirements document for human extraterrestrial missions. PSS approved the recommendation to be taken to the Science Committee.

PPS reviewed a letter to the SMD AA describing various areas of planetary protection concern. Dr. Buxbaum commented that there is an uneven understanding of Planetary Protection throughout the enterprise, and that it should be recognized that the merging of SMD/OCT/HEOMD does not lighten the load for PP. Dr. Rummel suggested adding a sentence about re-establishing a planetary protection requirements document for human extraterrestrial missions, believing that the PPO is well within her portfolio to proceed with a new NASA Policy Requirements (NPR) document. PPS tentatively planned a meeting for late September 2012.

Dr. Levy adjourned the meeting at approximately 4:20P.

Appendix A
Attendees

Planetary Protection Subcommittee Members

Eugene Levy, *Chair Planetary Protection Subcommittee*, Rice University
Greg Baecher, University of Maryland
Colleen Cavanaugh, Harvard University
Catharine Conley, *Planetary Protection Officer*, NASA
Peter Doran, University of Illinois/Chicago
Joanne Gabrynowicz, University of Mississippi
Victoria Hipkin, Canadian Space Agency (by teleconference)
Gerhard Kminek, European Space Agency
Gary Lofgren, NASA JSC
Robert Lindberg, National Institute of Aerospace
Jere Lipps, University of California, Berkeley
Claudia Mickelson, Massachusetts Institute of Technology
Carle Pieters, Brown University
John Rummel, East Carolina University
Andrew Steele, Carnegie Institution of Washington
Michel Viso, CNES
Amy Kaminski, *PPS Executive Secretary,* NASA HQ

NASA Attendees

Ralph Beaty, NASA RMD
Max Bernstein, NASA HQ
Janice Buckner, NASA HQ
Karen Buxbaum, NASA JPL
Jason Dworkin, NASA GSFC
T. Jens Feeley, NASA HQ
James Green, NASA PSD
Doug McCuistion, NASA PSD-MEP
Michael Meyer, NASA HQ
Curt Niebur, NASA HQ
Marion Norris, NASA HQ
Michael New, NASA HQ
Heather Smith, NASA HQ
Perry Stabekis, NASA HQ
Mary Voytek, NASA SMD

Non-NASA Attendees

Fabien Armogathe, EADS Astrium
Linda Billings, George Washington University
Jon Calomiris, Sotiria Science
Geoffrey Collins, Wheaton College
Andreas Frick, George Washington University
James Head, State Department
Rakesh Mogul, SETI
Joan Zimmermann, Zantech IT

Appendix B
NAC Science Committee Membership

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

Gregory B. Baecher
Professor of Civil Engineering
University of Maryland

Penny Boston
Department of Earth and Environmental Science
New Mexico Tech

Colleen Cavanaugh
Biological Laboratories
Harvard University

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

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

Amy Kaminski, Executive Secretary
Senior Policy Advisor, Office of the Chief Scientist
NASA Headquarters

Joanne Gabrynowicz
Editor-in-Chief, Journal of Space Law
University of Mississippi School of Law

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

Robert Lindberg
President and Executive Director
National Institute of Aerospace

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
Joseph A. Hannah Professor of Integrative Studies
Michigan State University

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

Subcommittee Administrative Support:
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. Mars Exploration Program Update; *Doug McCuistion*
3. Update on the Planetary Protection Office; *Catharine Conley*
4. Mars Science Lander Lessons Learned and Planetary Protection Knowledge Capture Activities; *Karen Buxbaum*
5. Strategic Knowledge Gaps: Planning for Safe, Effective and Efficient Human Exploration of the Solar System; *Michael Wargo*
6. Update on Office of Chief Technologist: Space Technology Program; *Prasun Desai*
7. Overview and Summary of a Life Detection Protocol Update Workshop; *Catharine Conley*
8. Result of ESF Study: Background and Draft Conclusions; *Gerhard Kminek*
9. Special Government Employees Ethics Briefing; *James Reistrup*
10. Planetary Protection of the Hayabusa 2 Mission; *Hajime Yano*
11. OSIRIS-Rex Asteroid Sample Return Mission; *Jason Dworkin*
12. SSB Report on Solar System Icy Bodies; *Geoffrey Collins*

Appendix D
Agenda

NASA Planetary Protection Subcommittee
Meeting Agenda
May 1-2, 2012
NASA Headquarters, Room 3H46

May 1, 2012

8:30 am	Welcome/orientation	Amy Kaminski and Marian Norris, NASA HQ
8:40 am	Words from the Chair	Eugene Levy, Rice University
9:00 am	Update on SMD/Planetary Science Division/ Mars activities	Jim Green, NASA HQ
10:00 am	Break	
10:15 am	Update on planetary protection activities	Cassie Conley, NASA HQ
11:00 am	Mars Science Laboratory lessons learned and planetary protection technology knowledge capture activities	Karen Buxbaum Jet Propulsion Laboratory
11:45 am	Lunch/update on HEO activities	Mike Wargo, NASA HQ
12:45 pm	Update on OCT activities	Prasun Desai, NASA HQ
1:30 pm	Discussion with SMD Associate Administrator	John Grunsfeld, NASA HQ
2:15 pm	Break	
2:30 pm	Technology implications from joint ESA-NASA Workshop on Life Detection in Returned Samples	G. Kminek / C. Conley
3:15 pm	Results of ESF study on risk assessment	G. Kminek
4:00 pm	Discussion	E. Levy/all
5:30 pm	Adjourn for the day	

May 2, 2012

8:30 am	Overview of the day	E. Levy / A. Kaminski
8:45 am	Mandatory ethics briefing	Jim Reistrup, NASA HQ
9:45 am	Hayabusa-2	Yano Hajime Japan Aerospace Exploration Agency (JAXA)
10:30 am	Break	
10:45 am	OSIRIS-REx	Jason Dworkin NASA Goddard Space Flight Center
11:30 am	Discussion	
11:45 am	Lunch	
12:45 pm	SSB Study on Planetary Protection for Icy Bodies	Mitch Sogin Marine Biological Laboratory
1:45 pm	Public comment	
2:00 pm	Discussion and recommendations	E. Levy/all
4:00 pm	Adjourn	