NASA ADVISORY COUNCIL

Planetary Protection Subcommittee

May 10-11, 2011

NASA Headquarters
Washington, D.C.

MEETING MINUTES

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Eugene Levy, Chair

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George Tahu, Executive Secretary

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May 10, 2011

Welcome and Orientation

Mr. George Tahu, Executive Secretary of the Planetary Protection Subcommittee (PPS) and Ms. Marian Norris made logistical announcements.

Words from the Chair

Dr. Eugene Levy, Chair of the PPS, welcomed members to the meeting. Members of PPS and attendees introduced themselves around the room. Dr. Levy addressed PPS issues for both the immediate and long-term perspective. Long-term, the subcommittee must assess planetary protection issues raised by Decadal Survey recommendations for future exploration of the Solar System. In the shorter term, PPS must confront Mars Science Laboratory (MSL) issues, given the current understanding of ice distribution on Mars. PPS also recognizes the need for resource allocation to understand planetary environments targeted by missions, and technology development for planetary protection. PPS must also evaluate NASA's posture to U.S. non-governmental missions (such as Google Lunar X-Prize) that raise planetary protection questions, and questions of protecting historical sites and artifacts from earlier missions.

Recent Progress in Planetary Protection

Dr. Margaret Race participated via teleconference as Planetary Protection Officer (PPO) Dr. Catharine "Cassie" Conley presented a brief background on Planetary Protection, which seeks to preserve planetary conditions for future biological and organic constituent exploration, and protect Earth and its biosphere from potential extraterrestrial sources of contamination (forward and backward contamination, respectively).

These activities are also based on international obligations, including those articles codified by the Outer Space Treaty of 1967, proposed to the UN in 1966 and ratified by the US Senate in 1967. In particular, Article IX states that parties to the treaty should explore space in such a way as to avoid contamination or adverse changes in the environment. The Committee on Space Research (COSPAR) of the International Council for Science represents an international consensus policy of guidelines for implementing planetary protection requirements. NASA also follows COSPAR policy in planning its robotic missions. Dr. Levy commented, with respect to forward contamination, that protocols are designed to preserve the ability to perform science investigations well into the future, as opposed to ethical considerations. These protocols and overarching philosophy apply in particular to

the three bodies in the Solar System that are thought to be able to support Earth organisms, or life similar to that found on Earth: Enceladus, Europa and Mars. The Space Studies Board (SSB) also provides overarching advice on planetary protection requirements. NASA planetary protection policy is embodied in NASA's policy document NPD 8020.7G; for specific robotic mission requirements, the document of reference is NPR 8020.12D.

Major activities underway at PPO are preparation for future missions, monitoring of existing missions, policy development, and program management. SSB has recently completed the Decadal Survey for NASA's Planetary Science Division (PSD); planetary protection technology will be essential to Decadal Survey goals in exploring Mars, Europa and Enceladus. The Agency is also preparing for the MSL launch, as well as the Russian mission Phobos-Grunt (which will carry hardware from a U.S. nonprofit company). The involvement of private U.S. entities in international space exploration missions raises questions regarding U.S. compliance with the Outer Space Treaty when NASA is not involved.

MSL carries a radioisotope power source (Pu) and has the potential to radiate heat for a long period of time. Recent data obtained at Mars suggest that the spacecraft could possibly produce an impact crater 5 meters deep, and that subsurface ice and hydrated minerals may produce water ice in the presence of a radioisotopic source during such an impact.

Regarding updates to policies and requirements, several milestones have been reached since the previous PPS meeting: a robotic requirements document has helped increase coordination between the European Space Agency (ESA) and NASA. Dr. Conley noted that plans for human missions to other planetary bodies would require similar documentation; therefore PPO is coordinating with NASA's Chief Health & Medical Officer as necessary. Improved coordination between agency-level policies for future missions are underway, and there are plans to hold a joint meeting between NASA and ESA advisory committees.

Programmatic considerations

Future missions will require more resources for planetary protection; the Planetary Protection Resources (PPR) program has selected one proposal, and its funding is still in jeopardy. Planetary protection has established a core capability at the Kennedy Space Center (KSC), which is essentially a microbiology research laboratory for training courses and mission activities. Implementing the Decadal Survey missions will require planetary protection implementation on a scale not

previously encountered; funding has not yet been identified for these new methods. It was made clear that PPO is involved in the Office of Chief Technologist's (OCT) road mapping process. Dr. Conley concluded her presentation with a request for new PPS candidates.

Vision and Voyages: 2013-2022 Planetary Decadal Survey

Dr. Pascale Ehrenfreund described the contents of the recently released Planetary Decadal Survey from the National Research Council (NRC). Released every 10 years, the Decadal Survey (DS) provides the primary scientific input to NASA and the National Science Foundation (NSF), and is used to design their programs of planetary science and exploration. The DS is science-driven, and entails heavy community involvement, with an emphasis on transparency and openness.

Five panels comprised the Planetary DS: Inner Planets, Mars, Outer Planets, Outer Planet Satellites, and Primitive bodies, all of which were led by a steering committee. The community contributed a large amount of input through many town hall conferences and white papers (199). The draft report was reviewed by 18 peer reviewers, including those from the international community. The DS was built around three themes: Building New Worlds, Planetary Habitats, and Workings of Solar Systems. Each theme identifies key science questions.

Building New Worlds considers the initial conditions of Solar System formation, processes of accretion, what governed the accretion, and the supply of water, chemistry, etc. Planetary Habitats explores the primordial sources of organic matter in planetary habitats, and the possibility of the presence of past aqueous environments on other planets. The Working of Solar Systems views the giant planets as laboratories to understand Earth and extrasolar planetary systems, as well as the evolution of planets. Twenty-five mission candidates were chosen for detailed studies, performed at the Jet Propulsion Laboratory (JPL), the Applied Physics Laboratory (APL), and Goddard Space Flight Center (GSFC). In addition, independent cost estimates were performed in conjunction with these studies, in response to concerns over mission cost growth. Technical, schedule and cost risks were evaluated by Aerospace Corporation. All costs were estimated in FY15 dollars.

Mission prioritization was based on science return per dollar, programmatic balance, technological readiness, and availability of appropriate trajectories. The DS recommended that ongoing and approved missions should continue, subject to Senior Review: MESSENGER, Dawn, Kepler, GRAIL, New Frontiers (1-3),

Cassini, MSL/MAVEN, and LADEE. The Research and Analysis (R&A) program also received strong support, with a call to increase its budget by 5% above the approved FY11 budget, and then 1.5% above inflation in subsequent years. The DS also recommended that technology development be developed and carefully protected, and funded at 6-8% of the total PSD budget. The DS strongly endorsed the Discovery program and recommended it be continued at its current funding level, with a cost cap per mission adjusted for inflation, and selection every 24 months. Discovery is not considered to be an exclusively inner-planets program, as illustrated by the comet hopper mission and the ethane/methane mission on Titan. The DS also endorsed the New Frontiers (NF) program, which can address high-priority missions, and recommended changing the cost cap to $1B (in FY15 dollars), excluding the launch vehicle cost. Further, it was recommended to select NF-4 and 5 missions in the decade 2013-2022, and to select NF-4 from among comet surface sample return, lunar South Pole/Aitken basin sample return, Saturn probe, Trojan tour and rendezvous, or Venus In Situ Explorer mission candidates, in no relative order of preference. For NF-5, the DS recommended selecting from among the remaining candidates from NF-4 plus Io Observer or a Lunar Geophysical Network.

Flagship missions in priority order: begin a Mars Sample Return (MSR) campaign with a de-scoped Mars Astrobiology Explorer-Cache (MAX-C 2018)/ExoMars, followed by a de-scoped Jupiter/Europa Orbiter (JEO); Uranus Orbiter and Probe; Enceladus Orbiter; and Venus Climate Mission. MAX-C 2018/ExoMars is envisioned as a NASA/ESA collaboration. Originally the mission concept had planned for two rovers to begin a multi-decadal campaign for Mars sample return. For this decade, the DS recommends caching only. Planned de-scopes must also be equitable between ESA and NASA; it is very likely that there will be one rover. If the (U.S) cost cap for this mission cannot be kept to $2.5B, the mission should be deferred to another decade or cancelled. The second-priority Flagship mission, JEO, is an orbital tour of the Jupiter system, followed by an Europa Orbiter at a 100-200 km orbital distance. Estimated cost for this mission is $4.7B. JEO would fly only if funding becomes available, without eliminating other recommended missions. The immediate goal is to reduce cost. Flagship priority 3 would be either a Uranus or Neptune Probe; the concept has not been well studied. Uranus, however, has a more favorable trajectory for the decade under study. A probe would perform remote sensing of the planet's rings, magnetosphere, atmosphere, and satellites.

Launch vehicle costs have increased in both the U.S. and Europe, thus the DS recommends steps to reduce costs, such as by including two spacecraft on one vehicle when possible, block buys of launch vehicles, and mass reduction. The DS also considers Pu-238 to be critical to Outer Solar System missions. JEO should switch to ASRG development (which require substantially less Pu); and ASRG development should receive attention comparable to a flight project.

The DS also recognizes planetary exploration's interaction with human exploration—it is vital to maintain the science focus of peer-reviewed missions to the Moon, asteroids, and Mars and its moons.

On 26-27 May, ESA delegates will decide whether ExoMars will go forward.

PSD Response to Decadal Survey

Mr. Jim Adams, Deputy Director for PSD, presented the division response to the Decadal Survey. The division's current commitments are top priority, followed by Technology Development, R&A, NF, and Discovery. The FY12 budget decimated outyear planning. However, at $1.2B per year, PSD still has an amazing planetary program, and PSD is trying to meet the constrained budget with de-scopes and delays. Budget planning is being centered on operating missions and missions in development, current R&A, in-space propulsion technology, the radioisotope power program, and Pu-238. PSD is capping R&A at $200M/year, and has put the next Discovery Announcement of Opportunity (AO) at the current 36-month cadence; all subsequent AOs will be scheduled on a 24-month cadence. PSD plans to maintain the NF schedule and has extended a mission budget for all operating missions subject to Senior Reviews. It has also dedicated a Lunar R&A wedge that has been transferred to PSD R&A. The residual Lunar Quest program will move to Discovery, and JEO has been de-scoped to studies funded through FY11/12. There is no JEO instrument AO, although there is a budget for some radiation technology efforts. Overall, the number one priority is to make MSR fit into the program. Dr. Lindberg asked if PSD had considered commercial launch vehicles. Mr. Adams responded that PSD will use them when they get to category 3. Only Atlas V and Delta II fit this category at present. NASA is currently prohibited from buying foreign launch vehicles.

Overall PSD program content

PSD recognizes that a partnership with ESA on MSR is critical, and the 2018 Mars mission will be a 50-50 share with ESA. The formal PSD response to the Decadal Survey is in the form of 200 recommendations catalogued into 37 actionable recommendations. The final written response to the DS is due in July 2011.

Discovery 12 selections

Future Discovery selections will alternate between solar and radioisotope powered missions, due to the cost of launch vehicles. The Discovery 12 selections are:

Comet hopper (Chopper), a rendezvous-and-landing, seven-year mission to comet Wirtanen (Jessica Sunshine, PI). Chopper will make measurements on the comet, study the structure of the nucleus, and will use radioisotopic power. The Advanced Stirling Radioisotope Generator (ASRG) for this mission will be at TRL-6 by the time of the downselect (NASA/DOE/Lockheed Martin are building the ASRGs).

The second selection is the Geophysical monitoring station (GEMS) on Mars (Bruce Banerdt, PI), which could supply some collaborative science contemporaneous with the presence of MSL on the surface. GEMS is a seismic experiment, derivative of the Phoenix mission.

The third selection is the Titan Mare Explorer (TiME), a boat to float on the methane lakes of Titan (Ellen Stofan PI) TiME would spend 96 days on the surface at Titan's *Ligeia Mare* methane lake; the mission hopes to demonstrate that an Outer Planets mission can be accomplished on a Discovery-class budget.

<u>Discussion with Ed Weiler: Future Challenges for the Science Mission Directorate</u>

Dr. Ed Weiler, Associate Administrator of the Science Mission Directorate (SMD), discussed the current state of the directorate. Dr. Levy commented that the rapid response to ESA has been beneficial for the Decadal Survey and asked if SMD were taking sufficient account of partnerships. Dr. Weiler replied that the future depends more and more on collaboration, most importantly in the monetary sense; ESA is no longer a minor player in space and can deal with NASA on equal footing; ESA and NASA scientists also have common goals for Mars exploration. If the two agencies don't work together, neither will have a Mars program. It is also recognized that smaller space agencies can join in the collaboration, and that MSR must be accomplished over a number of opportunities. Dr. John Rummel commented that PPS already has a relationship with ESA, via membership; and that continuation is important. Dr. Conley reiterated the commitment to planetary protection across the board with ESA; the International Mars Exploration Working Group is still active in this respect as well.

Dr. Levy commented that the availability of resources for technology development in planetary protection, and technologies to implement them (such as better containment, biological assays), seem to be falling through the cracks. Dr. Weiler

strongly urged that PPO consult with OCT on generic technology development, as well as the PSD technology program (there is an opportunity to compete for 6-8% of the PSD budget).

Dr. Rummel lamented the structure of the NASA Advisory Council (NAC) and the continued lack of a PPS voice within that structure. Dr. Weiler agreed with the sentiment. Dr. Penny Boston felt that R&A gets sacrificed in the current budget scenario, and that capping the program at $200M cheats the fundamental engine that drives advances. Dr. Weiler replied that the missions would argue otherwise; he worried most about being careful about duplication between NASA and NSF. NSF's charter is supporting fundamental science in the U.S.; therefore one could argue that R&A is their purview. NSF has $5B for science; anyone in planetary science could approach NSF for grants. NASA's rationale for R&A is to support missions. R&A is being protected, in fact, by PSD's actions. Dr. Andrew Steele remarked that the DS is obsolete already, because the budget is so prone to market forces. Dr. Weiler agreed that it is clear that NASA won't be able to do the lower priority Flagship missions; the DS functions instead as an architectural design for the future.

Subsurface Ice at Mars

Dr. Michael Mellon presented a review of the potential for ice and water at the equatorial regions of Mars. It is speculated that there are varying states of water on Mars today: in the form of vapor in atmosphere and soil pores; in the form of ice in polar caps, surface frost, ground subsurface; and in the form of liquid in gullies and on brines, ponds, subsurface aquifers; adsorbed as omnipresent on mineral surfaces; and as mineral hydration.

Mars is cold and dry; the global average temperature is 205K. It can get above freezing at noon at equatorial surfaces. There is about 0.03% water in atmosphere, about 10,000 times less than that on Earth. Overall, Mars is too dry for liquid water to persist, and too cold for vapor to condense as a liquid (with regional variations). Numerous theoretical studies over the last 4 decades support the concept of ground ice at Mars; ground ice is stable where soil temperatures are cold relative to the atmospheric frost point. Key factors that control ground ice stability are thermal inertia, albedo, elevation, ground temperature, and humidity. Regolith and atmosphere will exchange water over time; ground ice should condense poleward of about 45 degrees latitude. Equatorial ground ice should sublimate over time.

Gamma ray and neutron spectroscopy results indicate that the geographic and depth distributions agree well with neutron patterns: observed ice is in diffusive equilibrium. Polygonal patterned ground formations are also ubiquitous on Mars; these formations are indicative of thermal cracking over ice-rich permafrost; their locations are consistent with ice stability. Phoenix landing site trenches indicated icy soil; and ice-table depths at the site were consistent with diffusive equilibrium with the current climate. Recent impacts on Mars have also revealed icy substrates, locations also consistent with ice stability, in data obtained from the CTX and HiRISE instruments. Ice may be exposed subsurface ice or post-impact condensate.

Theory and observation are in good agreement—ground ice is observed where it has been predicted, and observed ice table depths are congruent with theory. What is the potential for ground ice in equatorial regions of Mars? Equatorial ground ice is generally not stable, and widespread equatorial ice not consistent with observations. It is difficult to make ground ice stable equatorward of 35 degrees latitude. At equatorial latitudes, when left to sublimate, unstable ice in equatorial regolith will be lost; regolith will become desiccated down to a few hundred meters. There would have to be a deep source of water to maintain an initial ice-rich soil deposit. For ice to persist, Mars would need ice trapped beneath an impervious layer, which is possible if there is a deeper source of water (i.e. ground water).

Climate change and the tilt of planet's spin axis is the biggest driver of ice formation, controlling polar sublimation and atmospheric water; and decreasing ground temperatures. Higher obliquity means warmer poles and a cooler equator. In current conditions, equatorial ice should not persist today, except where it was most recently stable. Poleward tilt reduces insolation (exposure to sun) and cools ground surface—under the right conditions this may result in ice stability. Equatorward tilt will warm the ground and destabilize any ice that is present. The interaction of CO_2 frost and shallow ground ice also comes into play; there are some theoretical assumptions supporting the idea that CO_2 properties maximally favor ground ice at lowest latitude.

There are two main types of mineral hydration at Mars: physically adsorbed water on the surfaces of substrates, and chemically bound water that is integrated into the mineral structure such as sulfates, phyllosilicates, zeolites; both of these types have been observed on Mars. Under Mars conditions, adsorbed water is about a monolayer thick, or less. Equilibration is rather fast, while diffusion in soil is slow. The best case for surface water could be made on slopes, where hydrated minerals reside.

MSL Landing Site Analysis

Dr. Ashwin Vasavada presented an overview of the 4 candidate landing sites for the Mars Science Laboratory (MSL). The Gale, Holden, Eberswalde and Mawrth Vallis sites all have morphological and mineralogical evidence of past water within the Noachian crust. Eberswalde appears to have a river delta deposit; and at its margins it appears to have phyllosilicate deposits. Gale has a 5-km sequence of layers that vary from clay-rich striae to sulfates at higher elevations. The Holden impact crater appears to represent an intrusion into an existing channel system, after which the crater flooded. Mawrth Vallis has the brightest spectral signature of clay minerals. All sites are considered low-risk for landing, thus it is hoped the final selection will be based on the best scientific rationale.

Early in the project, it was recognized that Entry Descent and Landing (EDL) failure could pose a contamination threat. The mission studied the scenario, modeled the temperatures, and the evolution of water. Analysis has revealed that liquid water, which might persist for a number of days, would be subsequently sterilized by the radioisotopic thermal generator (RTG). Dr. Rummel commented that liquid water could persist near 'dirty" pieces of spacecraft. Dr. Vasavada replied that the mission planners recognized this and accepted constraints accordingly.

Post-parachute failure ellipses have also been calculated: a failure in parachute deployment would result in impact of the vehicle some 9.7 km downrange of the target. Error ellipses were calculated for each site for planetary protection concerns. Water ice near MSL sites could take a number of forms: seasonal frost; adsorbed water; extant liquid water; exposed perennial ice or icy mantles; buried massive ice; buried ground ice; and chemically bound water (up to 10% by weight). What has been ruled out thus far is massive ice at meters to hundreds of meters of depth. Current water maps (based on gamma ray spectrometry) predict little chance of stable ground ice at any of the MSL sites.

Site analysis also included evaluation of fresh craters on Mars (dating to the last 30 years), which show ice occurring at the lowest latitude of 35 degrees. In terms of inferred ground ice, studies indicate that CO_2 frost is predicted, but absent on steep poleward-facing slopes down to 25 degrees latitude. Temperature and slope data were compiled for the MSL sites via instruments on Mars Global Survey and Mars Odyssey. (MGS-TES and ODY-THEMIS).

At the season of MSL EDL, the atmospheric pressure of Eberswalde and Mawrth Vallis will be below the triple point of water; the pressure at Holden will straddle triple point during the day. There is no known water or water ice at the sites, and the risk of undetected ground ice is very low; water frost, adsorbed water and water bound in minerals are possible, but relevance to planetary protection is either negligible or questionable. The worst case would be impacting a massive deposit of clays up to the 10% level (Mawrth Vallis); any water in this case would come off as quickly lost vapor. There will be a final planetary protection review at the final site selection review in June.

NASA-ESA Joint Mars Exploration Program Status

Mr. Doug McCuistion presented an overview of current Mars missions; the Opportunity rover continues to function but Spirit has remained silent. Deep Space Network (DSN) tracking of Spirit will end 31 May. MSL is doing well; MAVEN (a Mars aeronomy mission) was confirmed in 2010 and is moving to a critical design review (CDR) this year. ESA had a system-level System level preliminary design review (PDR) for EMTGO and passed NASA key decision point (KDP)-A in March 2011. The program has added funding to accelerate instrument builds.

Opportunity has traveled 28 km thus far and continues to do well mechanically. The Mars Reconnaissance Orbiter (MRO) continues to provide good science; MAVEN instrument development is well under way, and is meeting milestones. MSL has completed all environmental tests, and avionics are completed. Pre-shipment reviews have been done for the aeroshell and cruise stage; these will ship 11 May. Participating Scientist selections will take place in August 2011; the announcement received 149 proposals, of which 20 will be selected. The next landing site workshop for MSL is 16-18 May, and the final selection will be made in mid to late June. The launch window for MSL opens on November 25, 2011.

NASA-ESA partnership on Mars

The DS rated MAX-C as the highest priority flagship mission as long as it eventually leads to a sample return, and is de-scoped to $2.5B. The President's 2012 budget reduced the Mars Exploration Program (MEP) in the next decade's budget line. A bilateral meeting between NASA and ESA re-baselined the 2018 opportunity as a merger of ExoMars and the MAX-C rover mission into a single rover. Joint engineering and science working groups will carry out detailed studies, which are planned throughout the remainder of 2011 to reach a NASA Mission Concept Review in Spring 2012.

2016 mission EMTGO

The joint mission EMTGO is in phase A at NASA; ESA has been approved to begin its own implementation phase (C/D). NASA has created draft level 1 requirements; and NASA and ESA have agreed on a relay radio delivery schedule.

2018 Mission, Joint Rover

A "clean sheet of paper" 2-phase concept has been initiated for the 2018 mission. A planned portfolio carries through to the 2020s for eventual sample return. There will be a joint review in December that will enable planetary protection concerns to be addressed.

COSPAR and UN-COPUOS Activities

Dr. John Rummel reported on activities at the most recent Committee on Space Research (COSPAR)/UN-COPUOS symposium in Vienna, Austria. The COSPAR Panel on Planetary Protection, along with the Panel on Exploration, presented to the Science And Technology Subcommittee of the UN Committee on the Peaceful Uses of Space (UN-COPUOS), including various presentations on Outer Planets satellites, special areas on Mars, implementation of the UN Outer Space Treaty, etc. Participants agreed that it will become necessary to clarify and complement the legal regime governing the exploration of the Moon and other celestial bodies, and that a new policy instrument will be needed to protect science and historical artifacts, where needed.

COSPAR Bureau Actions included the institution of minor changes in category wording, essentially revolving around activities deemed to be "not compromising future investigation." A greater number of small bodies and satellites were added to target tables, and some calibration issues were clarified along with a listing of new guidance language that has been proposed for Kuiper Belt Objects (KBOs). A lifetime was imposed on trajectory biasing, simplifying and correcting a category IVb requirement for Mars. A requirement for containment of unsterilized samples returned to Earth from Mars was clarified, and a reporting requirement on recommending that COSPAR members inform COSPAR of plans was amplified. Other terminology changes replaced the term "bioload" with "bioburden." The symposium members also resolved to enhance awareness of the COSPAR Planetary Protection Policy, ensure that policies are known and accessible, encourage participation, and to provide start-up funding for an Internet presence. COSPAR voted to give this effort a budget at the level of €16,000 euro for the initial year, and a total of €51,500 through 2016. For legal purposes, Prof. Gabrynowicz recommended using "nongovernmental entities" as a term for "private space efforts."

Dr. Race asked how the issue of biodiversity on Earth is treated within COSPAR guidelines. Dr. Rummel replied that a request has been approved to study this question and took further discussion off line.

COSPAR Panel on Exploration

Dr. Ehrenfreund reported on the activities of the COSPAR Panel on Exploration (PEX). As COSPAR represents institutions from 44 member countries, 13 international scientific unions, and 5 associated companies, PEX strives to promote the use of space science for the benefit of mankind, and has produced a report on Space Exploration, which contains a summary of what has been accomplished, and information on international working groups, agreements pursued in the last decade, etc. PEX was founded in 2008 to address an international space exploration context, recognizing that a long-term, sustainable program requires alignment of all stakeholders with compatible goals. PEX promotes science as a driver for such a program, provides a summary of existing science roadmaps, and exploits synergies to support the development of worldwide space exploration programs while safeguarding the scientific assets of solar system objects.

PEX is studying several themes. Destination Moon is concerned with the early Earth-Moon system, terrestrial planet differentiation and evolution, solar system impact record on the Moon, and the lunar environment. Near-Earth Asteroids deals with the origin of the Solar System, organic materials, and expanding space flight beyond low-Earth orbit (LEO). The Mars theme revolves around determining if life ever existed on Mars, understanding the planet's climate, evolution of its surface and interior, and preparation for human exploration. PEX seeks to support the transition period toward global space exploration; stepping stones can be conducted in synergy with several stakeholders. An analog field program research is ongoing in parallel with PEX efforts, along with international exploitation of the International Space Station (ISS) in preparation for exploration. PEX also covers a worldwide small satellite effort in support of exploration (such as cubesats), and hitchhikers on missions to the Moon and Mars. PEX's Global Robotic Village theme represents a coordination of international surface and orbital elements for research, technology development and future human exploration. PEX is also in the process of evaluating an international sample return mission, such as a touch and go-based, sample return mission from a carbonaceous near-Earth asteroid. Human base studies are using Antarctica as a model and international arena, as a long-term science platform; this theme is also a part of the LEAG and ILEWG roadmaps. PEX can bridge the Earth and space communities by identifying and supporting the use of similar methods, concepts, and technologies.

The role of COSPAR PEX in space exploration is to promote and preserve science goals, provide a bottom-up structure for a global space exploration program, generate more active members and engage emerging nations, and secure political and programmatic stability. Protecting solar system environments and safeguarding scientific assets from human-induced activity is also part of its purview, as there is a greater need for environmental protection as commercial pressures increase. The current legal regime must be clarified and complemented, and additional regulations should be elaborated to ensure planetary protection. In the future, it will be necessary to further the international dialogue, encourage the adoption of supplementary agreements and measures, and a perhaps agree upon a designation of special management areas (planetary "parks"), codes of conduct, etc.

Future PEX activities will involve compiling data on environmentally damaging activities, holding regular workshops, and working with international scientific foundations.

PPS briefly discussed the issue of orbital debris. There is a set of UN Science and Technology Subcommittee principles that have been endorsed by the General Assembly, and a set of U.S. guidelines that are not legally binding, but NASA guidelines are the most detailed. The existing framework is a patchwork of voluntary guidelines. NOAA has regulations for commercial remote sensing systems that do not apply to NOAA itself. The Federal Communications Commission (FCC) also has some regulations on communication satellites; and there are international forums in the process of addressing the problem. Prof. Gabrynowicz observed that the FCC requires a license application, which includes a debris mitigation plan.

May 11, 2011

Overview of the Day
Dr. Levy provided an overview of the day's agenda.

Planetary Protection for Phobos-Grunt
Dr. Tom Duxbury, PI for the U.S. portion of the Russian Phobos-Grunt mission, gave an overview of the associated U.S. mission proposal that has been submitted to the Stand-Alone Mission of Opportunity (SALMON) call. ESA is also participating in the Phobos-Grunt mission, which aims to return to Earth a sample from the Mars satellite, Phobos. NASA's planetary protection officials visited with the Russians in 2009, and the Russian space agency has recently fed back to NASA their implementation approach. The SALMON grant is meant to support data archiving in NASA standard format; NASA will also support some key operations while learning how to effect sample return in the Mars vicinity. In terms of planetary protection, the Russian agency participates in COSPAR, and also maintains a PPO on the project.

Dr. Duxbury gave some science background on the mission. The best guess on the origins of Phobos and Deimos, estimated to be approximately 3.5B years old, would be that they arose from the great impact events of that era, which removed roughly a kilometer's depth of ejecta from the Mars surface. The current thought is that Phobos and Deimos are the two remaining moons of many that have escaped orbit, or have spiraled in to Mars. Phobos is on such a trajectory, and is expected to continue spiraling in toward Mars for the next 50 million years.

The Chinese have also made a government-to-government agreement with Russia to fly a spacecraft to Phobos, to ultimately orbit Mars; this mission was originally to launch in 2009. At that point, the U.S. became involved in instrument calibration and integration, and a two-year extension was requested to refine instrumentation. Launch is now planned for Nov 2011 from Baikonur; and from August through February 2012, the mission will go into a series of orbits around Mars, performing regolith sample return, and *in situ* study and remote sensing of the Mars environment. Mars system science will include a search for organics and varying isotopes once the sample is returned to Earth and analyzed. Return is scheduled to take place in 2014.

Additional U.S. involvement in the mission is through the Planetary Society via their Living Interplanetary Flight Experiment (LIFE), which entails flying a small

cassette containing living microbes to Phobos, and returning the sealed cassette to Earth in order to study the survivability of the organisms. The Moscow Space Research Institute (IKI) will also be sending a sample of small animals and plants for the same purpose. Dr. Duxbury reported that there is interest from Russia for a more expanded role for NASA, especially in the area of scientific involvement and possible sample sharing. Dr. Schwehm remarked that the biggest concern is that science operations at Phobos will be weak. The agency has had many anomalous experiences trying to land on other bodies. There is also some concern about friction between varying organizations such as Lavochkin vs. IKI. However, the mission is recognized as tremendously valuable for the NASA-ESA Mars program.

Planetary Protection for Phobos-Grunt

Dr. Cassie Conley reviewed planetary protection aspects of the Phobos-Grunt mission. The U.S. has some responsibilities re: the Planetary Society microbe cache. It is not clear however, how the U.S. would be held responsible in the case of a bacterial release on Phobos. The Chinese subsatellite is also going to be orbiting Mars, which has a much greater chance of impacting Mars than the Phobos-Grunt spacecraft. Planetary protection language from Russia indicates concern for both forward and backward contamination.

The mission has been assigned a Category V, Unrestricted Earth Return, on the basis of the Six Questions for small bodies (developed by the SSB). Beyond the Category V designation, the mission plan is to provide for tight sealing of the return capsule and strict containment of the returned samples, in compliance with a 1999 Russian law. Responsibility for Chinese satellite is carried by the mission's lead agency, per COSPAR policy. All participants would be responsible/liable in the case of a failure, however.

Roskosmos is following a Category III orbital lifetime approach for the mission spacecraft, and has also performed a maneuver-by-maneuver analysis. The Chinese YH-1 satellite's probability of impact on Mars in under 50 years was assessed at 0.03%.

NASA's PPO is assessing the probabilities for transfer of ejecta from Mars to Phobos or Deimos, with respect to age and location of craters on Mars, on timescales of 10,000 to one million years, varying amounts and size ranges of martian material, summary of assumptions, models, etc. Dr. Steele asked if PPO was assessing the probability of bringing back Martian material. Dr. Conley replied that if there were recent material from Mars mixed in the Phobos sample, a

restricted Earth return would be more appropriate. There was a brief discussion on known transfer times (shortest being 700,000 years), and the need to determine whether martian sediment can be brought back (as opposed to igneous Mars meteorites).

Dr. Conley reported that Roskosmos has performed much exposure experimentation at LEO on the ISS, and has brought back to Earth varieties of seeds, molds, fish eggs, lower crustaceans, insects, and bacteria. Phobos-Grunt will carry larvae, seeds, daphnia, and bacterial species including lyophilized *Streptomyces*, *Bacillus subtilis*, and *Pseudomonas*. The organisms will have their commensals included in the container.

PPS discussed the question of how to handle the Russian analysis of the mission lifetime, and acceptable terms for unrestricted Earth return, given the possibility of martian sediment returned in the sample, as well as off-nominal events. The mission has designed the capsules to withstand 3000 g of impact. Dr. Steele expressed concern over the very large number of organisms aboard the mission payload, and the possibility of bringing back Mars sediments. Dr. Boston commented that this mission constituted the first shot across the bow in sending humans (with organisms) eventually to Mars, and that Phobos-Grunt presented a critical case in planetary protection. Dr. Conley remarked that exploration can go forward as long as it is consistent with a policy to carefully minimize contamination. Dr. Stabekis noted that the Russians are treating the mission as a *de facto* restricted-Earth return; although not to the exact standard of the NASA process of categorization. Under COSPAR regulations the mission is unrestricted-Earth return. Dr. Duxbury suggested that someone from the curation office at Johnson Space Center might wish to expand NASA's involvement in the sample analysis. Dr. Stabekis commented that if Phobos-Grunt were to be designated as restricted, it would complicate matters unnecessarily. Prof. Gabrynowicz cautioned against imputation of knowledge among the involved parties. Dr. Levy pointed out that the international community recognizes Phobos as a Category V object, and that the question for PPS is limited to this categorization. Dr. Conley asked for feedback on addressing the implementation document from Roskosmos; specifically addressing whether they are compliant with the orbital lifetime requirement re: COSPAR. Dr. Levy promised to come back to the issue.

<u>NASA Innovative Lunar Demonstrations Data</u>

Mr. George Xenofos presented an overview on the Google Lunar X-Prize competition, a $30M effort to send a robot to the Moon, move the robot 500

meters, and transmit video, images and data to the Earth. Teams must be 90% privately funded; at present 29 teams (including international teams) are participating. NASA has decided to obtain engineering data from this project, as well as other commercial entities that are attempting to land on the Moon, that will help reduce risks associated with the development of lunar landers. NASA has issued a Broad Agency Announcement (BAA) with a maximum purchase allotment of $10.01M, under the title of Innovative Lunar Demonstrations Data (ILDD). Current ILDD tasks include basic capabilities in pre-launch, in-flight activities, and lunar landing. Enhanced capabilities include human mission profile landing, identification of hazards during landing, participatory exploration, imagery of the landing path, etc. The government is buying copies of this type of data, as specified for each contract (6 selections thus far from the 29 competitors). ILDD is looking for subject matter experts from Project Offices as needed for data evaluation and associated tasks. Six teams have been awarded ILDD contractors: Draper Labs, Astrobiotics Tech, Dynetics, Frednet, Moon Express, and MoonRise. Among the Google Lunar X-Prizes are incentives to visit Apollo and Surveyor sites. Historical site preservation is being evaluated, and NASA is currently determining recommendations, formulating mission design suggestions, and presenting them to the community. One team has the intention of coming within 500 feet of the Apollo 11 site. Dr. Doran suggested that there are some parallels here with Antarctica, and treatment of historical sites on Earth. Dr. Conley recommended that planetary protection language be included in these contracts. Prof. Gabrynowicz remarked that "keep out zones" imply an appropriation of lunar territory, which is prohibited; the involvement of nongovernmental entities also triggers Articles 2 and 6 of the Outer Space Treaty.

A meeting participant commented on the outcome of a meeting with the Google Lunar X-Prize group on artifacts, and felt that NASA needed to provide an agency position. However, NASA could approach the competition from a technical perspective, figure out the amount of ejecta kicked up by a lander, e.g., and create a technical recommendations document. NASA cannot regulate these activities, but can help guide them.

<u>NASA Role in FAA Licensing of Commercial Space Flight</u>

Ms. Anne Sweet, from the Space Operations Mission Directorate (SOMD), presented a briefing on how the Federal Aviation Administration (FAA) interacted with NASA in developing licensing procedures for commercial space transportation or experimental permits, given that such activities do not jeopardize U.S. interests. U.S. interests are defined as public health and safety, property, U.S.

national security or foreign policy interests, or international obligations of the U.S. The regulatory interest applies only to launches, re-entries or operation of launch or re-entry sites, in the U.S., or by a U.S. citizen outside the U.S. PPS discussed the implication which might allow FAA to have some jurisdiction over a payload that might threaten government property left on the Moon. FAA also issues remote sensing licenses and particular frequency and telemetry bands. Dr. Lofgren commented that the Apollo 12 spacecraft had a significant impact on the Surveyor site, landing 200 meters away.

Ms. Sweet explained that NASA interaction with FAA license requests currently occurs via communications with the Office of International & Interagency Relations, Office of Safety & Mission Assurance, and Exploration Systems Mission Directorate within NASA. Dr. Levy suggested SMD advice be solicited in these communications as well. Dr. Lindberg offered to talk with FAA to request *ex officio* representatives for the PPS.

Brown Bag Lunch

Prof. Gabrynowicz presented a lunch talk on the scientific principles underlying the framing of the Constitution.

Microbe on the Moon? Surveyor III and Lessons Learned for Future Sample Return Missions

Dr. Rummel put to rest the circulating rumor that *Streptococcus mitis* had survived on a Surveyor III camera on the Moon, in near vacuum, at a temperature range of -150 to 120 C. Apollo XII sampled Surveyor III for the presence of microbes (the camera was retrieved in November 1969). It had long been thought that repeated cycling to 120 C would have had a killing effect on the bacteria; but most believed that the camera never reached more than 70 C. No viable *S. mitis* was found on the camera, but was isolated from the crew in routine microbial testing. It is clear from retrieved film documenting the process that sterile procedures were not carried out appropriately and the camera was not bio-isolated, nor were negative controls used. The take-home message is that robotic sampling can solve many contamination problems posed by human sampling.

Civil Space Program

State Department representative Mr. Jim Head made some remarks pertinent to space policy. Citing his training in planetary science, he informed PPS that he will be in office until 2012, and hope to serve as a resource to PPS. He is currently on leave from Raytheon, and was part of the Astrobiotics group. He noted that the

State Department largely agrees with the conversation on FAA; and he acknowledged the gaps in how to deal with commercial efforts to go to Moon. There is a liability convention dating to 1971 that may be useful in such matters. International space treaties can also be enforced largely through diplomatic channels. Liability can be addressed through Claims Commission. Mr. Head suggested it would be helpful for PPS to do more to classify historical sites (crashed spacecraft, Apollo, Surveyor).

Discussion

Dr. Levy presented four items to consider as findings, the two most urgent being the response to MSL landing sites and the Phobos-Grunt mission. Other issues needing attention were: How commercial launch applications are reviewed, and the question of NASA participation in the Google Lunar X-Prize competition.

Speaking of MSL sites, Dr. Rummel felt there had been nothing in the presented material that indicated a problem, given present knowledge. Some further information might be needed on downward trajectories, how they were generated, and how different the flight system is than that outlined in the white paper. Ice in the equatorial zone is only remotely possible in its ability to affect landing sites. Dr. Steele also saw nothing that was inconsistent with the criteria. Dr. Levy agreed that the candidate sites seem generally compliant. PPS found it reasonable to say that the reanalysis of the distribution of ice on Mars does not alter the prior categorization. Dr. Doran sought some clarification on the fresh water calculations. Dr. Hipkin noted that during the Phoenix mission, two types of ice were seen, one type of which was very white, quickly sublimated. This ice was not sampled. The material actually sampled by Phoenix was akin to black ice. Dr. Conley commented PPS has not addressed CO_2 at the poles, which may impact atmospheric models, but which may not have impact on this particular case.

As to Phobos-Grunt, Dr. Conley recommended either accepting Russia's orbital lifetime assessments as is, or reconciling their protocol with NASA. Dr. Rummel suggested documenting the analyses for the future. Dr. Lindberg noted that the issue is whether PPO concludes whether this is an unrestricted or restricted category V Earth return. PPS considered commenting on the Planetary Society payload and how it affects the U.S. position of liability. Dr. Rummel was assigned to draft some language on the review of commercial launches, and the subcommittee deferred the finding on Google Lunar X-Prize missions.

Dr. Levy adjourned the meeting at 3:52PM.

Appendix A
Attendees

Planetary Protection Subcommittee Members

Eugene Levy, *Chair Planetary Protection Subcommittee*, Rice University
Greg Baecher, University of Maryland
Penny Boston, NMT
Colleen Cavanaugh, Harvard University
Catharine Conley, *Planetary Protection Officer*, NASA
Peter Doran, University of IL/Chicago
Joanne Irene Gabrynowicz, University of Mississippi School of Law
Victoria Hipkin, Canadian Space Agency
Gerhard Kminek, European Space Agency
Robert Lindberg, National Institute of Aerospace
Jere Lipps, University of California/Berkeley
Gary Lofgren, NASA SSC
Jon Miller, University of Michigan
John Rummel, East Carolina University
Gerhard Schwehm, European Space Agency
Andrew Steele, Carnegie Institution
George Tahu, *PPS Executive Secretary,* NASA HQ
Michel Viso, CNES

NASA Attendees
Marc Allen, NASA HQ
Joe Bredekamp, NASA HQ
Karen Buxbaum, NASA Jet Propulsion Laboratory
Nancy Carosso, NASA GSFC
Phil Crane, NASA HQ
T. Jens Feeley, NASA HQ
Robin Frank, NASA OGC
Jeff Grossman, NASA HQ
John Guidi, NASA HQ
David Liskowski, NASA HQ
Sheree Marambio, NASA HQ-OIIR
Meredith McKay, NASA HQ-OIIR
Steve Mirmina, NASA HQ
Mike Moore, NASA HQ
Sarah Noble. NASA HQ
Marian Norris, NASA HQ
Arik Posner, NASA HQ
Jonathan Rall, NASA HQ
Mike Reddy, NASA HQ
David Seal, NASA JPL
Mitch Schulte, NASA HQ
Perry Stabekis, NASA HQ

Anne Sweet, NASA HQ
Dan Woods, NASA SMD
Paul Van Damme, NASA Jet Propulsion Laboratory
Mary Voytek, NASA HQ
George Xenofos, NASA JSC

Non-NASA Attendees
Cathy Angot
Linda Billings, George Washington University
Jon J Calomiris, Sotiria Science
Tom Duxbury, George Mason University
James Head, State Department
Bill Mackey, CSA
Mike Mellon, University of Colorado
Margaret Race, 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
Professor, Earth and Environmental Sciences
University of Illinois at Chicago

Joanne Irene Gabrynowicz
Professor and Director
National Center for Remote Sensing, Air, and Space Law
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
Institute for Coastal Science and Policy
East Carolina University

Andrew Steele
Geophysical Laboratory
Carnegie Institution of Washington

George Tahu, Executive Secretary
Program Executive for Mars and Lunar Exploration
NASA Headquarters

Agency Representatives:

Dale Griffin
Environmental/Public Health Microbiologist
United States Geological Survey

Victoria Hipkin
Program Scientist, Planetary Exploration
Canadian Space Agency

Gerhard Kminek
Planetary Protection Officer
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. Overview of Planetary Protection; *Catharine Conley*
2. Vision and Voyages: 2013-2022 Planetary Decadal Survey; *Pascale Ehrenfreund*
3. Planetary Science Division Response to Decadal Survey; *James Adams*
4. Subsurface Ice at Mars; *Michael Mellon*
5. Mars Science Laboratory Landing Site Analysis; *Ashwin Vasavada*
6. NASA-ESA Joint Mars Exploration Program Status; *Douglas McCuistion*
7. Activities of the COSPAR and the U.N. Committee on the Peaceful Uses of Outer Space; *John Rummel*
8. COSPAR Panel on Exploration; *Pascale Ehrenfreund*
9. Planetary Protection for Phobos-Grunt; *Catharine Conley*
10. Microbe on the Moon?; *John Rummel*
11. NASA Role in FAA Licensing for Commercial Space Flight*; Anne Sweet*
12. NASA Innovative Lunar Demonstration Data*; George Xenofos*

Appendix D
Agenda

Planetary Protection Subcommittee Agenda
NASA Headquarters, Washington D.C. May 10-11, 2011
Dial in # 1-888-455-9745, passcode "PPS"
Webex registration (required): http://tinyurl.com/3zpcda9
Webex Meeting #: 993 322 987

May 10, 2011		**Room 5H45**
9:00 am	Welcome, Orientation, Introductions	George Tahu and Marian Norris, NASA
9:05 am	Words from the Chair	Eugene Levy, Rice University
	PLANETARY DECADAL SURVEY DISCUSSION:	
9:15 am	Overview of Planetary Protection context	Cassie Conley
9:45 am	Vision & Voyages: 2013-2022 Planetary Decadal Survey	Pascale Ehrenfreund
10:30 am	Break	
10:45 am	Planetary Science Division Response to Decadal Survey	Jim Adams
11:30 pm	Discussion: future challenges for the Science Mission Directorate	Ed Weiler
12:00 pm	Lunch	
1:15	Subsurface Ice at Mars	Mike Mellon
	Mars Science Laboratory Landing Site Analysis	Ashwin Vasavada
2:45 pm	Break	
3:00	NASA-ESA Joint Mars Exploration Program Status	Doug McCuistion/Michael Meyer
	INTERNATIONAL CONTEXT FOR PLANETARY PROTECTION	
3:30 pm	Activities of the Committee on Space Research (COSPAR) and United Nations Committee on the Peaceful Uses of Outer Space	John Rummel
4:00 pm	COSPAR Panel on Exploration	Pascale Ehrenfreund
4:30	Discussion	E. Levy/G. Tahu
5:00 pm	Adjourn for the day	
Evening	Group Dinner TBD	

May 11, 2011		**Room 9H40**
9:00 am	Overview of the Day	E. Levy/G. Tahu
9:15 am	Case study: Phobos Grunt	Conley
9:45 am	Discussion	

US CONTEXT FOR PLANETARY PROTECTION

10:15 am	NASA Role in FAA licensing of Commercial Space Flight	Anne Sweet
10:30 am	Break	
11:00 am	NASA Innovative Lunar Demonstration Data	George Xenofos
12:00 pm	Lunch	
1:15 pm	Discussion and Recommendations	E. Levy/G. Tahu
4:00pm	Adjourn	