

NASA ADVISORY COUNCIL

Planetary Protection Subcommittee

August 4-5, 2010

NASA Headquarters
Washington, D.C.

MEETING MINUTES

Eugene Levy, Chair

George Tahu, Executive Secretary

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*Prepared by Joan M. Zimmermann
Harris Corp.*

August 4, 2010

Welcome and Introduction

Dr. Eugene Levy, Chair of the Planetary Protection Subcommittee (PPS), welcomed members to the subcommittee's second meeting after a nearly two year hiatus, noting that the meeting took place at a time of challenge at NASA. Mr. George Tahu, the new Executive Secretary of the PPS, made a few logistical comments. Dr. Levy reviewed the regulatory and scientific roles of the PPS, observing that NASA has been addressing issues that are not in the purview of other agencies, particularly the nature and origin of life in the universe, an integral part of biology. He felt that the subcommittee must battle the perception that planetary protection is apart from the main NASA mission. To the contrary, it is the core of human thought and requires attention appropriate to its importance, as well as a proactive stance in assuring that appropriate steps are taken to enable answers to scientific questions. There are few objectives that can be botched as badly as biological objectives. This responsibility thus falls on the PPS. The regulatory responsibility of the PPS remains related to international treaties that govern space exploration, and includes the challenge of backward contamination to the Earth's biota via extraterrestrial organisms, as well as forward contamination to bodies in the universe.

Planetary Protection at NASA/Overview

Dr. Catharine (Cassie) Conley, Planetary Protection Officer (PPO), reviewed the goals of NASA's planetary protection efforts as codified in NASA policy documents, which include seeking an understanding of how the Solar System supports life, how life evolves in the Solar System and universe, and defining the hazards that could affect the extension of human life into space. Planetary environments are now known to be quite diverse—cold and dry like Antarctica, or in places like the subsurface on Mars, similar to the subsurface of Earth, implying that terrestrial organisms could survive there if introduced. Europa may have magmatic activity and subsurface volcanoes, also similar to some environments on Earth, and is thus susceptible to terrestrial contamination.

To prevent such contamination, NASA designates a PPO to certify planetary protection requirements to the Science Mission Directorate (SMD) Associate Administrator (AA) in these matters, and to make requests to the Space Studies Board (SSB), PPS and other advisory groups for guidance. The PPO is currently in the process of revising NASA policy documents that govern robotic activities, and the PPS will be consulted as part of this activity. In addressing such things as sample return, several reviews are held in preparation for these missions with the assistance of advisory bodies. Routine PPO advisory needs are review of mission activities and the provision of advice on implementation; recommendations on specific policy points not addressed elsewhere; and guidance on programmatic direction and issues relevant to future missions (such as Mars Sample Return: MSR). Missions now under consideration that will require PPS scrutiny are the Cassini Solstice-Extended Mission and its end-of-mission scenario; an Odyssey Mars Orbiter orbit-raise maneuver; Juno mission planetary protection implementation; and implementation options for MSR and the Outer Planets Flagship (OPF) mission.

Preventing contamination of Solar System bodies, including icy moons, is governed by a formulation based on cruise survival fractions, radiation survival fractions, etc. of particular organisms of particular types. A request has gone to the Space Studies Board (SSB) to review and update the specific factors included in this equation as applied to icy bodies in the Outer Solar System, the result of which will be returned to NASA and transmitted to the international Committee on Space Research (COSPAR).

Dr. Conley reported that the current requirements for Mars have a hole, in that the requirement for probability of failure on Entry, Descent and Landing (EDL) parameters is not well characterized. Increasingly complex EDL scenarios are being developed for future missions, and human error has been a notable contribution to past failures. Additionally, definition of planetary protection requirements for

MSR, particularly in the context of international cooperation, must be expanded and detailed. A major concern exists for the ability of future Mars/Europa missions to sufficiently eliminate organisms on spacecraft, so as to avoid contamination of both planetary environments and scientific samples.

Programmatic considerations for the PPO include an increasing number of missions targeted to planets of planetary protection concern. Technology development approaches, new directions in spaceflight, and increasing international space exploration activities, commercial exploration, and historical/environmental protection (there are no regulations governing this latter area at present), are all areas that require attention. Ideally, all space-exploring agencies and companies should hold parallel policy with regard to planetary protection requirements. The question remains, however, how to ensure compliance by agencies with the Space Treaty. Dr. Levy expressed skepticism that the PPS has commercial activity within its purview. Dr. Conley demurred, noting that at the COSPAR level, planetary protection policy is very explicit, and does apply to activities of private entities, although it does not confer authority on protecting cultural artifacts. Dr. John Rummel pointed out the lack of policy regarding nuclear disposal in space, with some conflict on policy for orbital debris, and hence was unsure from where such advice should spring. Mr. Perry Stabekis noted that there has been some call to add ethical considerations to the COSPAR planetary protection policy. Dr. Levy averred that the committee's mandate as currently construed is to protect science, but to also recognize the balance of risk.

Dr. Conley noted that some level of contamination would have to be acceptable if humans are to go to Mars, and would require development, over the next several years, of a policy document parallel to that governing robotic exploration. An area of international law that may be relevant to these considerations is Maritime Law, which states that a plague-stricken ship on international waters is invariably sent back to its port of origin.

Dr. Robert Lindberg cited a new shift in FY11 to a more robust NASA technology program and asked if there were any connection forged yet with planetary protection. Dr. Conley responded that Chief Technologist Robert Braun is in fact a former member of the PPS and that planetary protection is explicitly called out in Office of the Chief Technologist (OCT) presentation charts. Dr. Rummel added that within the Mars Scout program in 2002, technology requirements had been fed into the Mars technology program, resulting in a biobarrier for the arm on Phoenix; but he noted also that the ability of SMD to maintain technology programs is usually robbed by mission overruns. Dr. Levy reiterated a previous intention to forward a formal recommendation addressing technology development for planetary protection. Mr. Doug McCuiston reminded the PPS that OCT is targeting to fund cross-cutting technologies, not mission-specific technologies; and was not sure that OCT recognizes that planetary protection technology development cuts across directorates. Mars technology development will be mission-specific in the outyears, and it would be useful for the PPS to help the NAC understand this planning element. Dr. Lindberg noted that the potential of human exploration changes that entire planetary protection requirement; the Exploration Systems Mission Directorate (ESMD) also has its own technology bucket that could support planetary protection, such as instrumentation for Europa. Dr. Michael Meyer felt that ESMD might be able to help on issues such as pinpoint landing. Dr. Levy called for a specific presentation from the OCT by the next meeting to help prepare a recommendation.

History of Planning for a Mars Sample Return Mission

Mr. Pericles Stabekis provided a history of the efforts in Mars Sample Return planning, dating back to 1973. Early planning had addressed some back contamination issues as well as a reference architecture that considered orbital rendezvous vs. direct return, and bus deflection vs. canister deflection methods. After workshops in 1973-74, the Jet Propulsion Laboratory (JPL) undertook a study to define specific needs related to sample acquisition and delivery, sample opening and science, and quarantine.

Requirements included sealing, sterile insertion, verification, and controllable safety features (including how to treat a breach with sterilization). At that time, no detailed requirements were developed for the event of a quarantine. A ten-year plan was developed in 1978 for a project line, with planetary protection-related science/technology developments, and a Mars Sample Return Facility (MSRF) management and construction policy that required certification of the facility at least 2 years before the return of samples.

In 1981, a study was concluded on an orbiting quarantine facility (Antaeus report). The International Space Station (ISS) has also been posited as a Sample Return Facility (SRF). Both of these latter concepts were ultimately rejected: an orbiting facility must eventually return to Earth, and astronaut contamination is considered too high a risk for ISS sample return.

In light of negative Viking mission results, there followed a significant hiatus in sample-return planning. Efforts were revived in the late 1980s, in preparation for a planned MSR mission in the late 1990s/early 2000s. The Apollo experience, the Antaeus report, work from various committees, etc., have since contributed to the 2002 Draft Test Protocol, which is now in the process of a 2-3 year revision period. The key findings of the Protocol were that samples must be contained as potentially hazardous, with no uncontained martian materials to be returned to Earth unless sterilized, requirement of a breaking of the “chain of contact” with Mars, prohibition of distribution of Mars material on Earth unless properly contained, and establishment of an SRF two years prior to launch. The Mars Sample Handling and Requirements Panel (MSHARP), established by the former NASA Space Science Directorate, also made relevant recommendations.

In the late 1990s, NASA initiated the 2003-5 MSR project and was issued the following planetary protection requirements: probability of impact on Mars less than 10^{-4} ; planetary protection Category III for orbiter and Category IVB for the lander (Viking level sterilization = 30 surface spores); and an organic materials inventory. These guidelines persist to this date. After these guidelines were issued, the project was given an alternative to system sterilization of the lander: the lander could be cleaned to Viking level, but the sample handling elements were required to be sterilized. This project was cancelled in 2000. Since 1997, new insight and understanding produced new results, allowing the 2002 Draft Test Protocol to incorporate lessons from the recent Genesis and Stardust missions. Guidelines were generally reaffirmed in a 1997 report by the Space Studies Board, reinforcing prior conclusions that advocated a strong conservative program of planetary protection for MSR, public engagement in its planning stages, and careful consideration of advisory committee findings and recommendations. In 2006, an international committee, iMARS, was established to develop an architecture and baseline requirements for an MSR mission, and released a report in 2008. Also in 2006, the Space Studies Board issued a report, ‘Preventing the Forward Contamination of Mars’ that proposed recommendations for sterilization of sampling tools, and a category requirement for orbiters and Earth Return, similar to prior findings.

The parachute on the proposed Mars return capsule has been identified as a weak link, thus it has been suggested that the capsule be beefed up rather than depend on a parachute for an intact landing. The human factor will make the biggest difference in this area. Dr. Rummel commented that past failures provide lessons that must be incorporated, helping to ensure that missions employ reliable people in a well-supported environment. The project culture of Cassini, providing for long-term, smooth operations, as well as ownership of the sample return, were proposed as two essential ingredients for MSR mission success.

Planetary Protection Considerations for Mars Sample Return (MSR)

Dr. Conley presented current issues surrounding an MSR mission. Mission constraints depend on the nature of mission and the target location, and must avoid unnecessarily stringent restrictions while ensuring appropriate protection. Examples of specific measures include reduction of spacecraft

contamination, restrictions on sample return handling, and constraints on spacecraft operating procedures. Five mission categories from Category I (no requirements for planetary protection) to Category V (restricted Earth Return from any Solar System body) are available.

Provisional requirements for MSR in the outbound mission phase have been set to protect Mars from Earth organisms. For sample return, the baseline requirement is to protect Earth from martian organisms, and to provide for life detection and biohazard assessment. The MSR mission will distinguish origins of biota and demonstrate that samples are safe for release from quarantine and for eventual sample distribution, with several implementation methods considered at a range of costs. Mars orbiters have been set at Category III, and will not have to meet orbital lifetime requirements if they achieve total bioburden levels of less than or equal to 5×10^5 spores. Most lander systems fall under category IVa, which means that they are restricted to a surface bioburden of less than or equal to 3×10^5 organisms, or less than or equal to 300 spore/square meter. Category IVb landers (landers that investigate martian life) require that the entire landed system be sterilized to a final bioburden below 0.03 spores per square meter of exposed surface; OR to levels of bioburden driven by the sensitivity of life detection instruments. Alternatively, the subsystems that are involved in acquisition, delivery or analysis of samples must be sterilized to these levels, and a means of preventing recontamination of systems and contamination of material to be analyzed must be provided. Category IVc landers, meant to explore Mars special regions (ice or water near surface of landing area), require that the entire landed system demonstrate a rigorous level of sterilization. If a crash would cause a high probability of contamination, the entire landed system must be sterilized to a surface burden of 30 spores, and a total of 30 plus 2×10^5 spores. By way of illustration, the Phoenix mission was categorized as IVc.

Unless specifically exempted, the outbound leg of an MSR mission is ranked at IVb to avoid false positive results, and requires that a sample container be maintained free of Earth contamination and sealed after acquisition of sample. A redundant fail-safe containment system, with a method for verification of operation before Earth return, is also required. Category V Restricted Earth Return requires break-chain-of-contact methods, reviews and approvals, a program of life detection and biohazard testing, or a proven sterilization process as an absolute precondition to controlled distribution for any portion of the sample. The PPS briefly debated the tension between geologists and biologists on initial sample testing. Dr. Rummel noted that the NRC seems to stipulate that if covalent bonds in a sample are broken by such methods as heat and gamma radiation, the long-chain molecules (presumably indicative of life) would also be presumed to be sterilized. It has also been suggested that the PPO investigate solvents for sterilization, such as hydrazine.

Dr. Conley summarized some SSB recommendations on Mars Sample Return:

- Samples should be treated as hazardous until proven otherwise;
- If sample containment can't be verified, the sample should be sterilized in space or not returned to Earth;
- The integrity of the sample should be maintained through reentry and transfer to a Sample Return Facility;
- Controlled distribution of unsterilized material should be permitted only if the sample is not biohazardous;
- Planetary protection rules should not be relaxed for subsequent missions without a thorough scientific review and concurrence by appropriate independent body.

In this context, Dr. Levy called for operational as opposed to metaphysical considerations for a sample return mission. Dr. Lindberg noted the Draft Protocol considers clear evidence of extinct life or extant life on Mars as an avenue leading to conservatism. Dr. Margaret Race commented that if the life found is fossilized, the presumption is that extant life is still possible.

Dr. Conley reviewed evolving guidelines for avoiding backward contamination in a Mars sample, noting that the Draft Test Protocol currently provides some high-level guidelines, including the concepts of a mobile retrieval unit, sample handling, and sample curation facilities, and steps that would be required before any terrestrial distribution of the sample. Implications of a “potentially hazardous” sample provide for the possibility of destruction or indefinite containment of a returned sample. NASA therefore must have a means of acquiring sufficient confidence on criteria for containment, must have approved protocols for containment and testing, must specify technical requirements that flow from the hazard assessment (such as impact on hardware and software), and must develop technology as dictated by hazard considerations. The European Space Agency’s (ESA) Planetary Protection Working Group has issued language that reflects similar guidelines, including severity/consequence levels for a loss of containment of unsterilized samples returned from Mars not based on expected or proven consequences but as conservative approach, in line with the 2009 NRC/SSB-MSR report, to be used for resource allocation. The ESA guidelines must be addressed in parallel with NASA as MSR goes forward. The PPS briefly debated the definition of terms and phrases with regard to risks and safety, and emphasized the need for a common terminology considering also public perception.

Science Priorities for MSR

Dr. David Beaty presented a briefing by teleconference, in concert with Michael Meyer, describing the function of the Mars Exploration Program Analysis Group (MEPAG), which serves an advisory function for the Planetary Science Subcommittee. MEPAG has considered sample return missions from Mars in several Science Analysis Groups (SAGs): the Next Decade (ND), Mid-Range Rover (MRR), 2 Rover, and End-to-End MSR campaign SAGs (2011 E2E-iSAG), most pertinently. The ND-SAG focused on defining eleven possible science objectives for an MSR mission. Attributes considered most important to such a mission are sample mass and total number of samples. The ND-SAG concluded that no single site could answer all 11 science objectives, which in turn has led to a prioritization of objectives and landing sites. Sample categories considered as necessary components of a returned sample are rock, regolith, dust, and atmospheric gas. A collection of multiple, diverse samples of rock is considered by far the most important scientific objective of an MSR mission. At least one large sample of regolith should also be collected. One sample of atmospheric gas, deemed representative of the entire planet, is considered sufficient sampling. The similarities and differences between samples in a “sample suite” were also considered, and are considered to be as important as the absolute characteristic of a single sample. A minimum number for a sample suite is 5-8 samples; thus the ND-SAG also found that mobility is needed to acquire such a suite. As an example, Burns Cliff has been identified as a sedimentary formation, interpreted as a source of diagenetic redistribution of salts. A set of samples would be needed from this site to demonstrate variation. Asked which measurement could be made better with a returned sample (versus a measurement made *in situ*), Dr. Beaty responded that an organic geochemistry assessment or isotopic ratios could be better sampled with an Earth return.

Attributes of sample collection that maximize scientific value were also evaluated by the SAG, including what constitutes the best tradeoff between mass of samples and number of samples. The 12g QUE martian meteorite, which was subsequently subdivided into 60 individual samples, is considered a good model for mass allocations for MSR. A draft sample size was given as 10g, varying portions of which can be used for nondestructive life detection and biohazard testing, and destructive tests for characterization (including carbon chemistry), general research, storage for future analysis, etc. Dr. Rummel commented that the more varied the sample, the more the mass would be necessary to accommodate planetary protection testing. Mr. Stabekis added that future Draft Test Protocol workshops will address the issue of layered core sampling to help ensure that the subsample is representative of the sample. Dr. Meyer noted that one could also be more intelligent in assessing which tests need to be done in advance.

Sample packaging and labeling needs to include airtight encapsulation to avoid volatile losses and general contamination. Dating igneous rocks may not require encapsulation, but the general thinking is that encapsulation should be the rule. The composition of the sample collection is envisioned as dust, ice, suites of sedimentary, hydrothermal, and igneous rocks, atmospheric gas, caches from previous missions, etc., and is based on a total mass of 670g (representing 325g of actual sample). Consensus has not yet been reached on this latter item.

The MRR-SAG found that the instrumentation capability should be the same regardless of whether the rover goes to a new unexplored site or a previously visited site, and that reducing the payload mass would limit the ability to select or document samples, and greatly increase science risk. Dr. Meyer commented that rovers carry about 15kg of instrumentation; the real issue is what can be fit onto the rover itself.

The 2011 Mars Science Laboratory (MSL) mission sites are also of interest to MSR. However, using MSR prioritization criteria, additional sites of high priority have been recognized for MSR that are of astrobiological interest, and these findings are supported by the community. MRR-SAG found that the best way to evaluate additional sites is via an open landing site selection competition that also includes sample return selection criteria. A major finding of MRR-SAG was that criteria for selecting the instruments that can carry out *in situ* measurements and collect samples should be merged.

The 2RiSAG has proposed primary scientific objectives for a 2018 dual rover mission. These are: past habitability of environments, candidate biosignatures, prebiotic chemistry, sample subsurface samples, and sampling of geologic and geochemical variation across a lateral surface. ExoMars (drilling) and MAX-C rovers (lateral) have been considered within the purview of these objectives.

MEPAG has just begun to charter the E2E-iSAG in order to consolidate and prioritize for a reference set of MSR science objectives. E2E-iSAG results will be used to derive science requirements for individual flight missions, and to enable trade space analysis. The SAG will also study instrumentation, site selection, sample criteria, reference landing sites, and inputs to technology planning. Dr. Levy felt that the SAG should consider inclusion of a planetary protection expert on the team; he then asked how much isolation would be provided to protect sample from sample, and to protect the sample from the inbound environment. Dr. Beaty replied that airtight seals are planned to prevent cross-contamination, adding that the purpose of the next study team was to determine this requirement.

Ultimately, MEPAG has identified six major criteria that would affect the ultimate scientific value of MSR:

- Landing site with outstanding samples
- Presence of 3 different types of sample
- Diversity of selection
- Documentation of sample context on Mars
- Condition of samples on receipt
- Minimum sample size

Current NASA thinking on MSR

Dr. Michael Meyer presented NASA's current planning for MSR. Due to 2008 budget difficulties, NASA and ESA recently decided to merge their resources to take advantage of the 2016/2018 Mars opportunities, signing an agreement to this effect in November 2009. On 2 August, NASA announced a selection for the 2016 ExoMars Trace Gas Orbiter, which had been decided by a joint, open competition. ESA will build the orbiter and demonstrate EDL technology. NASA will provide the launch, science instruments, and a communications relay package for the orbiter. A joint sample return campaign will begin in 2018 with a NASA solar-powered, medium-traverse rover that will collect a sample return cache.

The rover characteristics are to be determined, and will depend largely on battery lifetime. The ESA ExoMars rover will be focused on subsurface access. The 2018 opportunity is envisioned as a pair of NASA-ESA rovers for astrobiology/sample return cache.

Mars Sample Return mission elements include sending a rover to cache samples, followed by sending an orbiter (with Earth Return capability) or lander with a fetch rover and Mars ascent vehicle (MAV). The Mars orbiter would retrieve the sample and bring it back to Earth. Current mission planning provides 3 stable points in the architecture: the cache can sit on the surface indefinitely. The sample can be retrieved and parked in orbit, another point of stability. The third point is the sample retrieval itself, followed by return to the SRF on Earth. The multi-element architecture allows robust duration for collection of high-quality samples, technical robustness in that it keeps landed mass within current EDL capability, and spreads technical challenges across multiple elements. Programmatic robustness is also achieved in that the mission architecture allows incremental progress, spreads out budget needs, and leverages and retains EDL know-how. Dr. Rummel agreed that the architecture allows for each mission to stand on its own, somewhat. Dr. Meyer commented that in order to cache samples, the rover must be able to do science *in situ*, and the addition of the orbiter provides a locus for more instrumentation in addition to its telecommunication ability. However, NASA recognizes that the mission must balance science objectives and budget concerns against loading on instruments and rising costs.

The NASA Max-C rover (Mars Astrobiological Explorer-Cacher) concept includes a dual cache, establishes constraints for latitude and altitude and landing ellipse, and defines a mass margin. Mission implementation is conceptualized as having 2 rovers landed on one platform. Sample acquisition and caching architecture is currently notional, and includes a tool deployment device, a coring tool, and a caching subsystem. A Mars Sample Return Orbiter concept is also being fleshed out. A sample Capture/Earth Entry Vehicle with detection and rendezvous features and capture basket concept has been designed, based in part on concepts drawn from Genesis and Stardust observations. The proposed sample can withstand up to 50°C from heat of entry. The capsule must be retrieved in sufficient time to prevent overheating of the sample.

The current Mars Sample Return Lander concept includes a fetch rover to traverse a distance of up to 14km and transfer the sample cache by robotic arm. Up to one Earth year may be required to retrieve the sample from the surface. The MSL EDL system will feed forward (keeping the mass of MSR sub-elements similar), with plans to increase mass capability by 10%. The Sample Handling Element includes preliminary plans for ground recovery operations. Dr. Rummel recommended that planetary experts work with robotics on sample handling technologies; this would also reduce contamination risks.

Dr. Meyer summarized by describing Mars Sample Return as being supported by a strong scientific impetus, engineering readiness for sample return, and a resilient multi-flight element approach. MSR should be viewed as a cohesive campaign and not an isolated flagship mission. Mr. Rummel asked if the multi-element approach had been emphasized in discussions with the Decadal Survey committee. Dr. Meyer felt that the group would appreciate the subtleties, that they would be obtaining costed studies on the elements. Dr. Rummel cautioned that the planetary protection elements must also be costed out, as these could be discriminators.

Sample Return Planning and the Draft Test Protocol (DTP)

Dr. Margaret Race provided a brief history of methods for preventing backward contamination, dating back to the Apollo program, which had used a rigorous protocol based on animal studies. Many changes have occurred since that time, including various NRC studies and NASA Working Group results. Over the decades, the NRC has maintained its conservative stance toward sample return. Historically, there has been a planetary/geological versus biological tension in terms of how to deal with samples.

Currently there is no existing Sample Return Facility that meets both sample containment and science needs. Containment issues have been considered in a series of workshops that were implemented in 2000-2002 resulting in the publication of the Draft Test Protocol. These workshops focused on containment within a sample canister and BSL-4 receiving laboratory; life detection protocols; preliminary biohazard testing; oversight, certification, and verification of the receiving facility; legal requirements and compliance; and public information. In 2002, a Draft Test Protocol for Detecting Possible Biohazards in Martian Samples Returned to Earth was released. Dr. Karen Buxbaum and Mr. Stabekis emphasized the considerable amount of advance planning that had preceded the workshops.

The Protocol considered an exceedingly complex set of BSL-4 level biohazard testing standards, emergency plans for treatment of sample breaches, geochemical testing, sample distribution and curation, program management criteria, publishing rights, public communication, ethical questions, and treatment of contradictory or inconclusive results.

A 2009 NRC study concurs with previous findings of the Draft Test Protocol (DTP) workshops, but has additionally stipulated that containment methods should be verified, added the requirement for examination of samples at the microscale level, and development of criteria for sample release (specifics yet to be determined). Other concerns are environmental impacts, reassessment for the need for animal studies given advances in molecular biology, attention to false positives, public opposition, and wild cards (such as discovery of extraterrestrial life). Asked about hazards to animals versus hazard to environment, Dr. Race replied that the DTP had considered some extremophile data in the past, but since pathogens and hosts tend to evolve together, it is uncertain what relevance this may have to extraterrestrial life forms. Dr. Rummel noted also the problem of detecting organisms that don't metabolize for long periods (viruses and spores, e.g.). He added that the staff of a biocontainment facility should be subjected to long-term health monitoring, similar to NASA's monitoring of astronaut health.

Review of Draft Test Protocol for Martian Samples Returned to Earth

Dr. Gerhard Kminek addressed ongoing efforts of both NASA and ESA to review and update the Draft Test Protocol. One issue is to revisit the working level requirement of 10^{-6} for release of martian particles larger than 0.2 micron in diameter. Dr. Kminek noted in passing that manufacturing of high-potency drugs overlaps with some needs of a MSR containment facility – i.e. to protect the product/sample and the operator/environment.

At present, there is a joint effort between NASA and ESA to update the DTP. The goal is to set up team of 10-15 experts and revisit the DTP over the course of one year through a series of workshops, working meetings, and targeted analyses, with the results to be presented at COSPAR. The scope of the effort is to especially address sample heterogeneity and statistically representative sub-sampling, and confidence levels of analytic methods applied. The expected output will be a synthesis of all deliberations and recommendations, an estimate of the confidence level of analytical methods applied, an assessment of representative sub-sampling with statistical relevance, identification of requirements to avoid compromising the test protocol (i.e., preventing terrestrial contamination of a Mars sample), and identification of future research and development needs. Functional requirements for a sample containment facility have already been the subject of preliminary results from some ESA studies, which will be helpful in the process of evaluation. Dr. Levy felt that the joint NASA/ESA effort could support a call for more resources for R&D for planetary protection. Mr. Stabekis added that a determination as to which samples can be pooled and which cannot also needs to be made; one can either benefit or lose a lot from pooling. The other assumption is small biomass. Dr. Kminek agreed that a more informed discussion on the subsampling approach would be required. Dr. Victoria Hipkin noted that it would be wise to have actual users involved in the development of the DTP. Dr. Meyer added that a good example of a sampling problem would be measuring across a chemical sample gradient—i.e., must one sample every time the pH or MgO levels change in order to detect life?

Hayabusa Planetary Sample Curation Facility

Dr. Karen Buxbaum reported on a recent NASA trip to JAXA's Planetary Sample Curation Facility (Sagamihara, Japan) to examine how JAXA has prepared for Hayabusa's sample return mission from the asteroid Itokawa. The visit took place a month before the spacecraft landed. The primary purpose of the visit was to better inform the handling and analysis of the 10% of asteroid sample that is to be provided to NASA.

Dr. Buxbaum reported finding an impressive laboratory designed to support sample return, displaying a wide range of contingencies. The Japanese facility is the first non-NASA facility for curation of samples returned from space. The facility has special relevance for MSR in that it includes strategies and equipment for cleaning incoming flight hardware, as well as innovative particle-handling techniques and an elaborate system for collecting gases. The facility is comprised of 6 rooms for a total of 400 square meters, 60% of which is cleanroom. The facility cost \$10M to construct, and is located within a larger research building. The facility was built over 3 years, following a period of design activity.

Facility design requirements were not provided to NASA, but the Agency did obtain a list of functional capabilities and flow charts. Functional elements and space included an information room, monitoring room, class 10K manufacturing and cleaning room, sample preparation room, electron microscope room, large class 100-1000 sample handling room, single locker room, 2 separate garmenting areas, air showers, and entry ways. To test the facility without introducing contamination, analog particles of Ni-rich olivine were used, which are easily distinguishable from asteroid particles. Solid samples come into contact with quartz-glass dishes and tubes under clean N gas; these are closely analogous to NASA methods. Perimeter security is used all over the facility, but the laboratory system has numerous additional levels of embedded security. There is also a unique sample manipulation system that uses electrostatic force to manipulate small particles, using joystick control. Vacuum conditions are used only during the initial opening of the sample holder. Thereafter, a second-level clean chamber is designed to be operated under slight positive pressure, with clean N. Prior to opening, the Hayabusa sample underwent two rounds of CT examinations, which took place at a separate facility, to determine the state of the interior latches before opening. In addition, a multi-step process was used to clean the exterior spacecraft, including acid-base cleaning, autoclaves, organic solvents, etc. Molecular analysis of the surface was also performed, along with FT-IR analysis and surface roughness gauges. Whether capture cleaning solutions were used is unknown. In terms of scientific instrumentation, most analysis will be done elsewhere by PIs in a competitive manner. There is one spectroscope at the facility.

Planned sample mass allocation from the Hayabusa mission is 15% for preliminary examination, 15% for Japanese PIs, 15% for non-Japanese investigators, 10% for NASA, and 45% held in reserve by JAXA. Details of the curation process will depend on the amount and physical condition of the samples. The timeline will be dependent on the condition and quantity of samples, and is estimated to be about a year. JAXA is currently examining the small amount of sample.

While the facility was built expressly for Hayabusa, Dr. Buxbaum felt it could be adapted for future use, and that JAXA could provide valuable insights for the future. Notably, the facility incorporated a fair amount of commercial equipment. She also noted that the work space, however, was not very ergonomic. Mr. Stabekis highly commended their Japanese hosts in terms of both courtesy and forthcoming manner, and emphasized that the facility was designed to very specific terms.

Discussion

The subcommittee held a brief discussion on the re-communication of PPS recommendations resulting from its November 2008 meeting through the Science Committee of the NAC. Dr. Levy reported that two of these recommendations remained germane and had since been transmitted through to the NAC; namely

that NASA explore challenges posed to planetary protection by the potential advent of private sector exploration, and that the PPS be reconstituted in its original form (PPAC) so as to be a direct report to the NAC. Dr. Levy announced that the recommendation to reestablish PPAC in its original reporting capacity had been declined by the Chair of the NAC.

Dr. Levy requested that PPS members consider further recommendations about bolstering the funding for planetary protection R&D; to arrange for a briefing from OCT; and to develop a live working paper of issues for the PPS. Dr. Levy also called for a dedicated website to distribute informational materials more efficiently; this request was tasked to Mr. Tahu.

August 5, 2010

Morning introduction

Dr. Levy reiterated some of the previous day's issues, particularly in formulating a recommendation on the supporting technology budget and additional resources for the PPO. Commenting on the fluidity of the NASA program, he acknowledged continuing uncertainties but hoped for a better focus as future meetings proceeded. He asked that PPS members consider the appropriate frequency of meetings, a minimum of 3 per year, with perhaps a fourth conducted as a teleconference. He felt that any new formal recommendations to the NAC would probably not be crystallized before the end of the meeting in progress, but perhaps would be by the end of the next one. He also felt that the denied recommendation should not be ignored without a PPS response. Dr. Lindberg suggested consulting with Dr. Laurie Leshin of ESMD to help bring the issue to the fore. It was also noted that Dr. Nancy Ann Budden sits on the NAC Exploration Committee. Dr. Rummel commented that the NASA Planetary Protection Office is going to impose requirements because it must; this is also a legal issue. There is also the issue of public interest, which is independent of the bureaucratic issue.

Canadian Space Agency Update

Dr. Victoria Hipkin delivered an update on the Canadian Space Agency (CSA). CSA has been actively involved with human exploration through ISS, and has logged the third largest number of astronaut flights among space agencies. CSA planetary operations commenced in 1999; the agency has since contributed to Mars at the instrument level. The agency also maintains a science program, radar and atmospheric satellites, and partnership in the development of the James Webb Space Telescope (JWST). CSA was reorganized into three divisions in April 2010: Space Data, Information, and Services; Space Exploration; and Future Canadian Space Capacity. There is no longer a specific science division; however, this responsibility is now managed by the head of Astronomy and Planetary Missions. There is no designated PPO.

The goals of CSA's Space Exploration division include participation in MSR, continued participation in human exploration, exploiting the full utility of ISS, and Space Astronomy. An exercise is under way to develop a strategic plan to identify mission priorities for the next decade, and to plan for a significant investment in technology development. CSA's Exploration core covers the technology development area. The 2009 budget provided \$110M over three years to develop technologies to support space robotic vehicles. These technologies include Mars and lunar rovers as represented by three large rover contracts, two small rovers, large and small manipulators, as well as drills and corers. Dr. Hipkin noted that signature technologies such as vision systems for 3-D tomography and LIDAR on Mars were in fact CSA developments. The agency is also involved in two New Frontiers phase A studies for the OSIRIS and Moonrise missions.

A CSA working group is being formed on planetary protection and sample return policy development, with an eye to generating a more formal structure. This activity will begin in the Fall. The scope of the

working group will be to develop two draft policies focused on the definition of roles and responsibilities, reporting structure, and recommendations on a process that will help to establish standards. The group is recruiting members from CSA Exploration and Corporate, the international community, the Canadian Public Health Agency, external expertise in astrobiology and micro, space law. A draft policy is expected by Spring/Summer 2011. Dr. Kminek suggested that COSPAR be invited to participate in the working group and Dr. Hipkin concurred. The PPS expressed strong support for the working group's goals.

COSPAR panel meeting report July 2010 Bremen

Dr. Rummel reported on the most recent meeting of the COSPAR Panel on Planetary Protection, held in Bremen, Germany in July 2010. The meeting was divided into 3 sessions, along with poster presentations: policy and implementation guidelines; planetary protection mission implementation and status (including Phobos-Grunt, MSL, and Juno/Jupiter orbiter missions); and R&D activities, which constituted an international opportunity to compare notes on sterilization techniques, microbial detection, etc.

Proposals for COSPAR sessions in 2012 were considered during the meeting. Dr. Conley agreed to continue her role as UN reporter for COSPAR. The panel raised a Resolution on Technical Changes to the COSPAR policy of July 2008, in an effort to clarify requirements, more precisely define categories, develop guidelines on organic inventory, and consider trajectory biasing requirements for Mars. The resolution contains a suggestion to require that space agencies report to COSPAR before mission launches. Consideration of this resolution will be continued in March 2011.

The panel also discussed a Resolution on Enhancing Awareness of Planetary Protection, which was given an initial funding allocation of 10K euros, for a total of 50K euros over 6 years, with funds to be allocated through COSPAR Headquarters. The priority for this activity is to conduct initial visits to space agencies that have emerging awareness of COSPAR planetary protection policy. This resolution will also be continued to March 2011.

The COSPAR panel also reviewed resolutions related to ethics, proposed a workshop on ethical principles, and a colloquium on establishing risk levels for MSR. Dr. Rummel was reappointed to chair the panel until the 2014 assembly, and Dr. Kminek to vice-chair until 2012. The panel also made a request for the nomination of two new Vice Chairs for appointment by the president; two people who participate in the PPS have been named for consideration. Asked for a sense of what ethical principles might comprise, Dr. Rummel replied that he expected them to tie in to considerations beyond the biological, such as ethical consideration of life above and beyond science, and protection of sites for historical and aesthetic purposes.

ESMD Human Exploration and Robotic Precursors

Dr. Laurie Leshin, Deputy Associate Administrator of ESMD, provided an update on directorate activities, commenting that in these early days of enormous change for NASA, the level of uncertainty and range of possibilities remains high. The President's proposal for NASA is still awaiting budget passage, and a Continuing Resolution will likely govern the beginning of FY11. The proposed budget has effectively carved out a new path to develop knowledge and capabilities to support human exploration, balance large rockets with new knowledge and technologies for future space flight, and to reduce cost. The budget also represents a fundamental philosophical shift by allowing commercial concerns to transport astronauts to low-Earth orbit (LEO). ESMD is in the midst of a phased development strategy to build the foundation, develop systems, and enable sustainable exploration of the Solar System, along the guidelines of the Augustine report.

ESMD's strategy is to build through a steady sequence of achievements, akin to the Mercury and Gemini programs, and to do something more complex with each mission. A primary goal is to identify essential

capabilities needed for a Mars mission. New program planning is under way that has established initial plans for programs announced in the FY11 budget request, which allows NASA to make informed decisions and establish program objectives and expectations. To this end, ESMD has created a set of "Point of Departure" activities through the Human Exploration Framework Team (HEFT), and is considering asteroids as an early destination. HEFT will also prioritize missions to respond to possibly changing conditions. Planned programs and projects are divided into Human Research, Enabling Technology Development, Heavy Lift/Propulsion Technology, Flagship Technology Demonstrations, Exploration Scout missions (xScout), Commercial Cargo, Commercial Crew, and Emergency Rescue Vehicle. ISS has also been brought into the picture more prominently, extending to 2020 at least. The first destination of commercial crew will be the ISS. The ESMD budget total is \$4.2B for FY11.

Exploration Precursor Robotic Missions (xPRM) will be driven by needs for future human space flight; hazards and resources are of notable interest here. There will be specific opportunities to overlap with science in this program, both within SMD programs and processes, and in payload flights. xPRM will also provide technology flight demonstrations, coordinate with other NASA directorates, and foster competition. Point of Departure missions have been identified as a Near Earth Object (NEO) mission in 2014, a lunar lander in 2015, the Mars 2018 opportunity, and a 2018 NEO mission as a potential reconnaissance flight to prepare for human space flight to a NEO in 2025.

xScout missions are envisioned as PI-led or as small common-approach missions designed to reduce costs. They will be slightly higher in risk terms, more focused, and managed at a 18-24 month cadence. The biggest challenge will be launch vehicles. LCROSS is considered a good model for this type of program. The first launch is planned for 2014.

Asked to comment on the new OCT program, Dr. Leshin welcomed the new approach, which she considered more balanced overall, adding that ESMD would be more focused on mission pull, by contrast.

Enabling Technology Development and Demonstration objectives have been identified in ten foundational technology areas. Of interest to planetary protection are ground and flight demonstrations, and remote operations (telerobotic), possibly in preparation for asteroid operations. Larger-scale Flagship Technology Demonstrations will include advanced in-space propulsion; autonomous rendezvous and docking (ARD); inflatable habitats, advanced, closed-loop life support; propellant transfer and storage; and aero-assisted EDL.

ESMD's Human Research Program received a 42% augmentation in the proposed FY11 budget. This is an applied science program that is entirely risk-driven, designed to measure human health and mitigate risk. Space radiation, countermeasures, and behavioral health (important for long missions) are among its areas of focus.

Dr. Leshin expressed a strong willingness to continue ESMD dialogue with the PPS, and agreed that incorporation of planetary protection requirements must take place early in the mission-planning process. ESMD is starting the process of identifying planetary protection issues for NEOs, and will be holding a workshop the week of 9 August on objectives for NEO missions. New programs will provide near-term opportunities to continue research related to planetary protection, while an increased focus on NEOs and asteroids will necessitate new planetary protection considerations. Dr. Rummel commented that a 150-day mission on an NEO would provide a good analog laboratory for a Mars mission. Dr. Leshin noted that a human Mars surface exploration would continue to figure in future planning, but that is not a subject of near-term discussions with respect to planetary protection within ESMD. She concurred that there will be a need to facilitate more interaction between ESMD's Human Research and planetary protection. Medical

monitoring and planetary protection need to work together and practice those procedures on a NEO. Dr. Leshin reported being extremely open to planetary protection advice and welcomed ongoing feedback.

The PPS briefly discussed expected funding levels for robotic precursor missions. Noting that different budgets exist at different levels in the House and Senate, Dr. Leshin felt the worst case would be an instrument program with SMD and international cooperation. Dr. Lindberg asked how investment in planetary protection technology would fit in with OCT/ESMD technology development. Dr. Leshin suggested an OCT briefing to answer those questions. Dr. Rummel expressed concern that planetary protection recommendations have not been percolating through directorates and divisions, and called out the need to craft equivalent planetary protection requirements document for both human and robotic missions.

Discussion

The PPS discussed developing a framework for a planetary protection technology development initiative. Dr. Conley offered some documentation to help the effort along, including an internal list of needs compiled over the last 6 months, as well as a JPL document. Dr. Levy recommended placing these documents on a useful website. Dr. Buxbaum added that in 2005, JPL produced a book advocating 12 or 13 technologies useful in extreme environments, such as power, propulsion, planetary protection needs, and electronics, which could benefit from an update. Mr. Stabekis suggested that the PPS obtain a comprehensive briefing on advanced technologies that have been funded or identified as necessary; planetary protection experts have long advocated some technology push for its unique capabilities. Dr. Rummel commented that, looking at historical funding trends, technology investments tend to get eroded over time, and technology needs get lost at a higher level. There needs to be a way to defend technology lines for future missions. Dr. Buxbaum called for a willingness on the part of NASA programs to be more strategic in thinking, and to develop such things as sterilization techniques for a series of missions, rather than focusing on a particular mission at hand. Mr. Stabekis noted that there have been studies that identify no tall poles (no impossibilities) to system sterilization, and that sterilization also cuts across targets. Because sterilization is more than a Mars issue (applying also to destinations such as Europa), this could help support arguments for funding. Dr. Conley cautioned that Outer Planets and Mars projects have some common ground, and that therefore NASA should also guard against reinvention of technologies. Dr. Rummel commented that consistent technology efforts always suffer from the tendency to plug up problems, which argues for the establishment of separate long-term programs and continuity. Who holds the money and makes sure it gets spent on the right technology? Who is responsible for keeping the technology available? Should NASA directly fund centers for this capability? Contractor and research community participation will also be integral to technology development, to create a cadre of people who are familiar with the techniques. Dr. Conley noted that the PPO typically funds early technology development, which then suffers from a gap in funding, after which the project picks up the tab for final development.

Dr. Levy expressed concern about the human factor in the maintenance of continuous expertise, making an analogy to a loss of art and cultural transmission. U.S. planetary protection technology is not sustained anywhere else besides within NASA. Technology development must be considered in concert with cultural challenge, and support must be found for consistent funding of centers to create an institutional home for planetary protection. Dr. Buxbaum commented that the most consistent effort in this area is taking place in the OPF program; the only other credible discussion for large-scale sterilization was in planning for an astrobiology mission on Mars that was aimed at life detection. Dr. Buxbaum felt that technology development for MSR would soon shift to the significant problem of back contamination, as opposed to protecting Mars. Mr. Stabekis noted that if no credible plan existed for spacecraft sterilization, programs might avoid “hot” targets, illustrating how lack of capabilities can influence target choices.

The PPS debated the various influences of technology push and pull, and new sets of mission drivers that arise from such situations as the sticky scoop on the Phoenix sampling arm, or constraints governing astrobiology missions. Dr. Conley commented that the planned Mars Sky Crane may not meet bioburden needs if a two-rover mission is launched (the crane has electronic components that can't be baked). Dr. Levy pointed to the obvious need for high-temperature electronics, for example, for Venus missions. Dr. Rummel bemoaned the ignorance of what is available, and noted that there are in fact some high-temperature batteries for such purposes: no one really understands what is available on the shelf. Dr. Kminek cited basic research and technology budgets in the technical and science directorates at ESA that are used for planetary protection procedure and technology development to implement the requirements.

Cassini Planetary Protection Status

Dr. David Seal, mission planner for Cassini, presented a status of the Cassini mission with respect to planetary protection. The mission is focused on avoiding impact on Titan (of intermediate planetary protection concern but with a caveat to address contamination concerns through a probabilistic method, 10^{-3} probability of impact) and Enceladus (of high planetary protection concern due to evidence of liquid water under the surface; 10^{-4} probability of impact). Mission activities at this time are to address the probability of impact on Titan.

The Cassini spacecraft carries 3 radioisotopic thermal generators (RTGs) and hydrazine fuel. There are roughly 2 crucial activities per week, a high level of activity. Every orbit is different, reflecting changing geometries driven by Titan, which requires vigilance on the part of the mission team. Saturn is currently passing into Northern Summer Solstice. The end-of-mission scenario for Cassini will use one encounter with Titan to pass through the ring system, with an impact on Saturn to take place in September 2017. The entire end-of-mission phase is ballistic, with calculations showing that ballistic orbit is assured. There will be no communication with the spacecraft to verify this, however.

At present the overall health of the spacecraft is excellent. All engineering subsystems are fully redundant. Within subsystems, there has been some degradation in reaction wheel 3, and there are 2 degraded Z-facing thrusters on A-branch, which is not considered a loss of redundancy. Overall the mission team has 13 years of experience flying the spacecraft. There are two sets of eyes on every engineering uplink, and at least annual table top Operational Readiness tests. There have been a total of 5 safings during the mission; 4 attributed to sequencing errors, and one cosmic ray-induced power switch trip. The spacecraft remains fully capable of performing any maneuver within 12-24 hours, and there have been no safing incidents since 2003. Dr. Lindberg asked if a record was kept of near misses. Dr. Seal replied that the mission uses the ISA and PFR systems to write up surprises; these are closed out quickly. He added that recovery operations are streamlined such that high gain communications can be recovered within an hour.

In terms of consumables, there is a healthy positive margin for both hydrazine and bipropellants; these amounts are modeled in detail and reviewed every 10 weeks. All other consumables are healthy and/or not applicable for planetary protection. The main engine cover has exceeded its flight limit, with an approved waiver. There has been no change in its mechanical behavior since 2003. If it fails, it can be jettisoned. There should be 32.7 kg of bipropellant left by September 2017 (translating to a usable quantity of 10 kg). Monopropellant is expected to be 22 kg by 2017 (3.7 kg unusable).

Hazards relevant to planetary protection are dust impacts and general spacecraft failure in the condition of a potentially impacting trajectory. Saturn's radiation environment is benign to the spacecraft. Enceladus's plume is in the form of tiny particles at Cassini altitudes, and Titan atmospheric variations are well within control authority limits—if exceeded, a safety is tripped, with brief loss of control. The Saturn environment is dusty, with faint rings beyond main rings. Sophisticated dust models are in place, and total

potential risk to spacecraft has been calculated to be 1.2%, with a remaining potential risk estimated at 0.55%, mitigated partly by shielding. The prime mission limit on environmental hazards was 5%. The cumulative dust hazard risk will be highest toward the end-of-mission timeframe.

In terms of navigation, Cassini has had an average delivery accuracy to encounters of 4.8km; the average over the last 10 encounters has been 1.5km. Maneuver-supporting analyses and operations processes ensure maneuver reliability. The tracking schedule always allows for the loss of a single tracking pass; the mission has never lost a tracking pass on a primary maneuver.

The cumulative spacecraft failure probability was initially modeled as 1.75×10^{-5} per day. Solstice mission impact probability of impact to Titan is now calculated at 4.3×10^{-3} , and to Enceladus on the order of 10^{-5} . There remains room for more review to evaluate compliance to planetary protection standards.

End of mission options include an alternate scenario in which the mission could maneuver for an early Saturn entry. This scenario would require a high inclination angle, with time and velocity dependent on the initiation point. An emergency maneuver could retarget the spacecraft to an icy satellite, and may require a Titan flyby to achieve trajectory. Other options considered were exiting the system via Titan to eventually impact Jupiter, or escaping to a heliocentric orbit for perpetuity. Some stable orbit options have also been considered (500 yrs without impact), but would use up valuable fuel. The current end-of-mission scenario has been deemed the cheapest and fastest, with the highest scientific value.

Most newly discovered moons in the outer Saturnian systems were observed from ground-based systems. However, Cassini is credited with discovering Methone and Pallene, Daphnis, Polydeuces and Helene. The parent body of G ring was also resolved by Cassini (and confirmed a prior hypothesis).

Asked for the secret to Cassini success, Dr. Deal credited excellent teamwork devoid of personality battles, and an exciting pace of scientific discovery.

Discussion

Committee members discussed possible agenda items for future meetings, and asked for a status of current terms of reference for the PPS. Dr. T. Jens Feeley, Executive Secretary of the NAC Science Committee, reported that the terms are under review at Headquarters, but that the subcommittees are being advised to operate as if the draft terms were approved since the new version of the terms are more consistent with the approved NAC Charter than the 2006-era terms of reference.

Dr. Lindberg reiterated support for a visit to a BSL-IV tour, possibly Fort Detrick, MD or a curation facility at Johnson Space Center. Mr. Tahu reminded the PPS that it must follow an open FACA process to arrange the visit. Dr. Lindberg suggested it would be useful to have a final budget summary when it was passed. Dr. Conley added that the PPS might also do well to review historical levels of funding for planetary protection. Other agenda items including an OCT briefing, a presentation of specific planetary protection technology requirements associated with MSR, including TRLs of technologies baselined for MSR, particularly special requirements for a BSL-IV facility.

The PPS discussed where its purview began and ended in the BSL-IV facility. Dr. Conley suggested obtaining a briefing from NASA's man-rated system safety evaluators. Dr. Rummel felt that the man-rating process was too esoteric to properly derive probabilities. He added that the state of committee knowledge regarding methane on Mars, and other indications of special regions needed to be updated, as well as progress on discovery missions as they come along. Dr. Schwehm requested a briefing on recent MRO data, and Dr. Hipkin suggested that the existence of shallow ice at Mars mid-latitudes would also

warrant PPS review. Dr. Rummel averred that the 2018 cache site is uninteresting in terms of extant life. Dr. Conley noted that current return technologies cannot keep samples frozen, and recommended that ESA and NASA compare notes on technologies for sample return.

Dr. Rummel expressed concerns about last-minute changes in requirements as driven by scientific discoveries, or as re-routed by politics. Dr. Buxbaum wondered if planning for the 2018 Mars opportunity should include considerations for caching at a special region. Mr. Tahu reminded the PPS that the current plan is for caching capability in 2018, such that when the decision is made to fly a sample return mission, the 2018 cache is one option for returning a sample to Earth. However, the eventual first sample returned from Mars may not be the actual 2018 MAX-C cache. For architectures of sample return, this thinking is pre-decisional. Dr. Conley noted that none of these planned rovers can access a special region because they will not be sterilized, thus the decision has been made *de facto*. Dr. Rummel agreed, adding that unless a decision is made to enable whole-system sterilization, the 2018 rover will not visit a special region. Dr. Conley further suggested a presentation on EDL technologies and how they limit site selection. Dr. Hipkin commented that if one could eliminate uncertainty on the ability to sterilize systems, this might ease the conversation forward. Dr. Rummel pointed out that there are no current requirements to system-sterilize radioisotopic power sources; at present, the nylon gasket cannot be heat-sterilized. Proper engineering of systems (like building a bigger oven) will also take the pressure off program managers.

Dr. Levy asked Mr. Tahu to arrange a way to query members for the next meeting in the November timeframe. Dr. Kminek reiterated his request for members/expertise selection for revisiting the Draft Test Protocol. Mr. Tahu remarked that the revision of NPD 8020.12 is about to go through the review process. Dr. Conley said she hoped to have it on the agenda by the following meeting, with disposition of comments included. Dr. Levy adjourned the meeting.

Appendix A Attendees

Planetary Protection Subcommittee Members

Eugene Levy, *Chair Planetary Protection Subcommittee*, Rice University
Greg Baecher, University of Maryland
Catharine Conley, *Planetary Protection Officer*, NASA
Victoria Hipkin, Canadian Space Agency
Gerhard Kminek, European Space Agency
Robert Lindberg, National Institute of Aerospace
Jon Miller, University of Michigan
John Rummel, East Carolina University
Gerhard Schwehm, European Space Agency
George Tahu, *PPS Executive Secretary*, NASA HQ

NASA Attendees

Karen Buxbaum, NASA Jet Propulsion Laboratory
T. Jens Feeley, NASA HQ
Laurie Leshin, NASA HQ
David Liskowski, NASA HQ
Michael Meyer, NASA HQ
Mike Moore, NASA HQ
Marian Norris, NASA HQ
Arik Posner, NASA HQ
Mike Reddy, NASA HQ
David Seal, NASA JPL
Perry Stabekis, NASA HQ
Dan Woods, NASA SMD
Mary Voytek, NASA SMD

Non-NASA Attendees

Linda Billings, George Washington University
David Pittman, Chemical and Engineering News
Margaret Race, SETI
Ana Wilson, Harris Corp.
Joan Zimmermann, Harris Corp.

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

George Tahu, Executive Secretary

Program Executive for Mars and Lunar Exploration
NASA Headquarters

Ruth Faden
Johns Hopkins Berman Institute of
Bioethics
School of Public Health
Johns Hopkins University

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

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
Planetary Protection Officer
European Space Agency

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

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

Subcommittee Administrative Support:

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

Appendix C Presentations

1. Planetary Protection Overview, *Catharine Conley*
2. History of Planning for Mars Sample Return, *Pericles Stabekis*
3. Planetary Protection Considerations for Mars Sample Return, *Catharine Conley, Gerhard Kminek*
4. A Summary of MEPAG's Recent Thinking Re: MSR Science, *David Beaty*
5. Current Mars Sample Return Architecture Overview, *Michael Meyer*
6. Mars Sample Return Planning: Sample Containment and The Draft Test Protocol, *Margaret Race*
7. Hayabusa Sample Curation Facility Visit, *Karen Buxbaum*
8. Canadian Space Agency Update, *Victoria Hipkin*
9. COSPAR Panel Meeting, Bremen July 2010, *John Rummel*
10. ESMD Human Space Exploration and Robotic Precursor, *Laurie Leshin*
11. Cassini Planetary Protection Status, *David Seal*

Appendix D Agenda

Planetary Protection Subcommittee Agenda

NASA Headquarters, Washington D.C. Aug 4-5, 2010

Dial in # 1-866 631-9069, passcode 3062413

Aug. 4, 2010

Room 5H45

| | | |
|----------|--|-----------------------------------|
| 9:00 am | Welcome, Orientation, Introductions | George Tahu and Marian Norris, HQ |
| 9:15 am | Words from the Chair | Eugene Levy, Rice U |
| 9:30 am | Planetary Protection at NASA: Issues and Status | Cassie Conley, PPO/HQ |
| 10:00 am | Overview/History of Mars Sample Return (MSR) | Pericles Stabekis, Genex/HQ |
| 10:30 am | break | |
| 10:45 am | Planetary Protection Considerations for MSR | C. Conley/Gerhard Kminek, ESA |
| 11:45 pm | Discussion | E. Levy/G. Tahu |
| 12:15 pm | lunch | |
| 1:15 pm | Science Priorities for MSR | Dave Beaty, JPL/Michael Meyer, HQ |
| 2:00 pm | Joint ESA-NASA Mission Architecture leading to MSR | M. Meyer/Fuk Li, JPL |
| 2:45 pm | break | |
| 3:00 pm | Sample containment and the Draft Test Protocol | Margaret Race/Stabekis/Rummel |
| 3:45 pm | Hyabusa Sample Return/Curation Facility | Karen Buxbaum, JPL |
| 4:15 pm | Discussion | E. Levy/G. Tahu |
| 5:ish pm | Adjourn for the Day, Dinner | |

Aug. 5, 2010

Room 9H40

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|----------|---|------------------------|
| 9:00 am | Overview of the Day | E. Levy/G. Tahu |
| 9:15 am | Canadian Space Agency (CSA) update on policies for planetary protection and sample return | Victoria Hipkin, CSA |
| 9:30 am | COSPAR activities update | John Rummel |
| 10:00 am | ESMD Human Exploration & Robotic Precursors | Laurie Leshin, ESMD/HQ |
| 11:00 am | break | |
| 11:15 am | Discussion | E. Levy/G. Tahu |
| 12:00 pm | lunch | |
| 1:00 pm | Cassini Extended Mission and PP Plan | David Seal, JPL |
| 2:00 pm | Discussion and Recommendations | E. Levy/G. Tahu |
| 5:00pm | Adjourn | |