REPORT

COSPAR/IAU Workshop on Planetary Protection

Williamsburg, Virginia, USA

2-4 April 2002

Prepared by the COSPAR Planetary Protection Panel

John D. Rummel, Ph.D.
Chair

Report of the
Workshop on Planetary Protection

held under the auspices of the

Committee On Space Research (COSPAR)

and the

International Astronomical Union (IAU)

of the

International Council for Science (ICSU)

at

Williamsburg, Virginia, USA

on

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COSPAR, Paris, France
2002

COSPAR/IAU Workshop Report
Table of Contents

COSPAR/IAU Planetary Protection Workshop Report

Introduction

Solar system exploration as an international endeavor has entered a new era of activity and multinational cooperation. A number of the currently envisaged missions are targeted to bodies (e.g., Mars, Europa) that have significant interest with respect to the origin of life and chemical evolution, and the potential for biological studies. COSPAR has an important role as the organization that maintains internationally accepted standards in the area of planetary protection—a required reference for international missions to such bodies.

The COSPAR Planetary Protection Panel is concerned with biological interchange in the conduct of solar system exploration, including: (1) possible effects of contamination of planets other than the Earth, and of planetary satellites within the solar system, by terrestrial organisms; and (2) contamination of the Earth by materials returned from outer space carrying potential extraterrestrial organisms. The primary objectives of the Panel within COSPAR are to develop, maintain, and promulgate planetary protection knowledge, policy, and plans to prevent the harmful effects of such contamination.

Plan of the Workshop

During April 2-4, 2002, a Workshop on Planetary Protection was held under COSPAR auspices, with IAU cosponsorship, to undertake work of the Panel that cannot be done within the constraints of the 2002 World Space Conference (WSC), or later Scientific Assemblies. This Workshop was convened to organize, update, and improve COSPAR policies in the area of planetary protection—developing documents/resolutions to be considered by the COSPAR Bureau and Council at or before the time of the WSC. In particular the Workshop addressed the following areas of planetary protection policy:

- **Updating and consolidation of COSPAR's Planetary Protection Policy**, based on the draft presented at the Warsaw Scientific Assembly (2000), as a scientific standard for reference by spacefaring agencies for their own missions, and in the pursuit of international cooperative activities. This Policy is intended to focus on robotic missions, and to include:
  - Refinement of COSPAR policy to address the forward contamination of Europa and other bodies/sites that may support the growth and spread of spacecraft-introduced Earth organisms.
  - Development of COSPAR policy to address Mars sample return missions and sample return missions from small bodies of the solar system that may be capable of supporting life.
- **Specific issues** brought before the Workshop for discussion, comment, or resolution—including the planetary protection status of the upcoming Beagle-2 mission to Mars (ESA), and the MUSES-C asteroid sample return mission (ISAS).

The Workshop was planned to accommodate international attendees representing both COSPAR and IAU constituencies. It was announced in the IAU Information Bulletin #90 in late 2001, and a direct invitation to attend and/or to nominate attendees was made to the COSPAR Council in both October and December 2001. In addition, all COSPAR Associates who had participated in the COSPAR Planetary Protection Panel at Warsaw, in July 2000, were invited to participate in this Workshop. Despite travel constraints, a total of 32 people from 8 different countries participated in the meeting. Their names and address information are provided in Appendix F.

The Agenda of the Workshop is given in Appendix A. Background presentations were planned for the morning of the first day of the meeting, and subsequent days were devoted to the business of the Workshop, with Subgroups (see Appendix B) designated to develop topical inputs that were later discussed in plenary session. The Agenda fairly well represents what actually happened at the meeting—although a couple of the plenary discussion periods on the second and third days also encompassed the Beagle-2 and MUSES-C presentations and discussions. Appendices C, D, and E contain the text of the presentations made in plenary session during the Workshop.

Due to a series of changes (COSPAR 1964, 1969, 1976, 1984, 1994) that had been made in its planetary protection policy by COSPAR over the last ~40 years, the COSPAR policy had become fragmented and extremely difficult to reconstruct (see Rummel et al. 2002, for an attempt). Although the other objectives of the meeting were well-addressed (see below), the primary focus of the Workshop was the development of a stand-alone version of the COSPAR Planetary Protection Policy, for consideration and adoption as the COSPAR standard by the COSPAR Council and Bureau.

<u>Results of the Workshop</u>

Following a short presentation on the Planetary Protection Panel and an overview of the Workshop plan, Mr. Pericles Stabekis briefed the group on the existing COSPAR policy and its background (Appendix C). This provided the participants with a good grounding in existing policy, and set the stage for the first afternoon's deliberations by the Subgroups (Appendix B) on requirements for Mars, Europa, and Small Bodies, as well as the Policy Process/Implementation Subgroup. The first three Subgroups presented their deliberations for plenary discussion, and developed short Subgroup Reports that are provided here. The Policy Subgroup, working separately and in conjunction with the other three Subgroups, provided the Proposed COSPAR Policy (given below on page DP-[1]), as their report.

Subgroup Reports

A summary of the findings of each Subgroup is provided below, as they were brought forward for discussion. Subsequent discussions in plenary session determined the incorporation of each Subgroup's recommendations into the Proposed COSPAR Policy.

Mars Subgroup – The Mars Subgroup considered both forward contamination and backward contamination, in turn. Their considerations were based on the existing COSPAR policy for Mars (COSPAR 1994).

For forward contamination, under the existing Category IVa, the Subgroup recommended no change.

Under Category IVb, for missions designed to detect extant martian life, they recommended that the definition be expanded so that all of the requirements of Category IVa apply, along with the requirement that either, the entire landed system must be sterilized to *Viking* post-sterilization biological burden levels, or that the subsystems which are involved in the acquisition, delivery, and analysis of samples used for life detection should be sterilized to the *Viking* level, and a method of preventing recontamination of the sterilized subsystems is in place.

For missions which investigate martian special regions (see definition, below), even if the missions do not include life detection experiments, all of the requirements of Category IVa should apply, along with the following:

Sterilization to Viking post-sterilization biological burden levels is required,

- Case 1. If the primary landing site is within the special region, the entire landed system should be sterilized.
- Case 2. In the case where the special region is accessed though horizontal or vertical mobility, either the entire landed system can be sterilized OR the subsystems which directly contact the special region are sterilized to this level, and a method of preventing their recontamination prior to penetrating the special region are provided.

If an off-nominal condition (such as a hard landing) could lead to inadvertent biological contamination of the special region by the spacecraft, the entire landed system must be sterilized.

A "Special Region" is defined as a region within which Earth-sourced organisms are likely to propagate, OR as a region which is interpreted to have high potential for extant martian life forms. Given current understanding, this is thought to be regions where liquid water is present or may occur. Specific examples include but are not limited to:

- Subsurface access in an area and to a depth where the presence of liquid water is probable
- Penetrations into the polar caps
- Areas of probable hydrothermal activity.

The Mars Subgroup also proposed a Category IVd for Mars, to be assigned to missions designed to detect organic signatures of extinct or extant martian life, in addition to the requirements of IVa or IVb, with:

- The entire landed system cleaned below the threshold of the most sensitive instrument in the payload, OR
- The subsystems which are involved in the acquisition, delivery, and analysis of samples used in the experiments cleaned to this level, and a method of preventing recontamination of the cleaned subsystems in place, OR
- The preparation of the spacecraft resulting in a method to distinguish Earth-sourced contaminants from martian signal.

[This last recommendation (Category IVd) was not carried forward into the Proposed COSPAR Policy due to a lack of consensus on the scope of the requirement.]

For backward contamination prevention in Mars missions, the Subgroup recommended that the Earth return mission should remain Category V, "Restricted Earth return," with the following provisions:

1. The outbound leg of the mission shall be treated per Category IVb requirements, to avoid a "false positive" in the life detection and hazard determination protocol or in the search for

life in the sample after it is returned. A "false positive" would inhibit distribution of the sample from containment and would lead to unnecessary increased rigor in the requirements for all later Mars missions.
2. The sample container must be sealed after sample acquisition. A redundant fail-safe containment with a method for verification before Earth return shall be required. The integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving laboratory.
3. The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars, including but not limited to: no uncontained hardware that contacted Mars may be returned to Earth; and isolation from Mars shall be provided during sample container loading into the containment system, launch from Mars and in-flight transfer operations (if any).
4. Multiple reviews and approvals of the flight mission at three stages shall be required: prior to launch from Earth; prior to leaving Mars for return to Earth; and prior to commitment to Earth re-entry.
5. A program of life detection and "biohazard" testing, or a proven sterilization shall be performed as an absolute precondition for the controlled distribution of any portion of the sample.

The Subgroup also discussed the establishment of an international committee of relevant governmental and scientific bodies to oversee the design of the receiving laboratory and its operation, the design and the execution of the "biohazard" testing protocol, and the process for the release of any portion of the sample, but did not formally bring these items forward in its report.

Europa Subgroup—

The Subgroup provided the following discussion and recommendations:

In the exploration of the outer planets, Jupiter's moon Europa should be given special consideration. There is certain evidence that liquid water might exist beneath the icy crust which would be an energetically favorable environment for life (Space Studies Board 2000). Although it is premature to conclude that either an ocean or a biota exist on Europa, it is prudent to implement planetary protection procedures that assume the existence of both. Given the capabilities of terrestrial life to adapt to extreme conditions, such as heat, cold, pressure, salinity, acidity, dryness and high radiation levels as well as combinations of them, a conservative approach is recommended to be taken to protect the europan environment. Properties of the europan environment may present a target for contamination by terrestrial organisms carried on a spacecraft which could colonize the entire subsurface via the ocean connection.

The Subgroup recommended to classify missions to Europa as Category IV missions and that similar planetary protection requirements apply to any orbiter, lander and penetrator directed towards Europa. This is based on the consideration that orbiting spacecraft also have a significant probability of ultimately impacting on the surface. Any spacecraft component that is buried within the ice is effectively shielded from lethal levels of radiation, potentially allowing the survival of some contaminating organisms. Resurfacing episodes of the young europan crust could bring spacecraft components in contact with the ocean.

Therefore, the Subgroup [committee] agrees with the Space Studies Board report "Preventing the Forward Contamination of Europa" and recommends to COSPAR that the bioload on spacecraft sent to Europa must be reduced to such a level that the probability of inadvertent contamination of an europan ocean is extremely low (10^{-4} per mission). In view of the large uncertainties that are critical to estimating the probability of contamination, a special workshop is recommended in order to determine:

1. The level of probability of survival and growth of terrestrial microorganisms in the europan ice and ocean;
2. The research required to reduce the uncertainty in long-term survival of microorganisms in the Europan surface / near-surface environment and in the turnover time of Europa's icy crust.
3. The level of acceptable bioburden required for all parts of the spacecraft before launching.

The Subgroup also recommended measures for reduction and control of bioburden. To reduce the bioburden of the spacecraft, measures towards improving the clean room technology and cleanliness of all parts before assembly are essential. It is required to monitor spacecraft assembly facilities at a regular basis and understand not only the bioload but also microbial diversity to contain specific problematic species. Specific methods should be developed to eradicate problematic species. These methods of sterilization should reflect the type of environments found on Europa, enhancing concern about Earth extremophiles most likely to survive on Europa. Cold and radiation tolerant organisms should be targeted for alternative methods of sterilization on Earth, such as those using plasma, heat and chemicals.

In agreement with the SSB report *Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies*, (Space Studies Board 1998) it is recommended to classify missions to Europa that bring europan samples back to Earth as Category V missions, "Restricted Earth return." Containment of the material returned from Europa presents unique challenges. Sample return missions designed to pick up material from the surface of Europa will require several sample transfers to get the sample from the surface and into the ascent launch vehicle for sample return. Therefore, containment would increase in importance over that for Mars samples and possibly preclude distribution to the scientific community outside of containment. [This last point was not the consensus of the plenary.]

Small Bodies Subgroup—This Subgroup was charged with considering whether the SSB framework for sample return from small bodies should be adopted as COSPAR policy, and what concerns, if any, should be stated in the policy with regard to the forward contamination of small bodies.

After its deliberations, the Subgroup made the following recommendations:

1. That COSPAR adopt the SSB framework (SSB 1998) for sample-return from small bodies as part of the COSPAR integrated Planetary Protection policy
   - Accepting the SSB assessment of biological potential of small bodies as embodied by the six questions shown on the SSB chart (Fig. 1.1, pg. 18)
   - Accepting the SSB recommended approach to handling samples returned from small bodies (Table 8.1, pg. 79)
2. That COSPAR charge its Panel on Planetary Protection with:

- Responsibility for evaluating, on a case-by-case basis and at the earliest possible time in mission planning, that containment still is not, or is, warranted for samples returned from small bodies in categories Ib and II
- Responsibility for preparing a resolution for COSPAR approval that summarizes the conclusion of this evaluation.

[Recommendation 2 was not taken forward by the plenary session during the Workshop in this form, but was provided for as an option, if requested by the launching agency.]

3. That the membership of the COSPAR Panel on Planetary include expertise in areas relevant to these evaluations and be augmented on an *ad hoc* basis as needed.
4. That the COSPAR Panel on Planetary Protection accept the SSB recommendation that containment is not warranted for samples returned from the asteroid target of the MUSES-C mission based upon the Panel's assessment of the mission and the assessment of the NASA Planetary Protection Panel.

   [See below for the report of the plenary discussion of MUSES-C.]

The Subgroup also made the following recommendations on Forward Contamination:

1. That COSPAR recognize the applicability of the SSB evaluation of the biological potential of small bodies to considerations of forward contamination concerns.
2. That the COSPAR Panel on Planetary Protection sponsor a workshop at the next COSPAR Scientific Assembly to evaluate the following policy statements regarding controls on forward contamination for missions to small bodies (Table references in SSB 1998 report).
   - For small bodies in Table 8.1 that are representatives of a very large class of objects, imposing forward contamination controls is not warranted, regardless of category
   - For all other bodies in Table 8.1, forward contamination controls must be evaluated on a case-by-case basis, regardless of category
   - Prepare a resolution for COSPAR approval that summarizes the conclusions of this evaluation

[The workshop may be implemented for the 2004 COSPAR Assembly, since at the time of the Workshop it was too late to implement such a session at the 2002 World Space Congress.]

MUSES-C Presentation and Discussion

At the request of the Japanese Institute for Space and Astronautical Science (ISAS), and Environment Australia, the Workshop considered the case of the MUSES-C mission, which is intended to return a sample from an S-type asteroid, 1998 SF36, in 2007. The Workshop heard presentations from Professor Akira Fujiwara of ISAS on the mission, and from Dr. John Rummel of NASA on the deliberations of NASA's Planetary Protection Advisory Committee about the mission and its target body (see Appendix D).

After careful consideration with respect to the revised COSPAR policy presented in this report, the Workshop agreed to the following statement regarding the mission and its planetary protection categorization:

> "The COSPAR Workshop on Planetary Protection considered the categorization of the MUSES-C mission, and concurred with the recommendations of the NASA Planetary Protection Advisory Committee on the Muses-C mission, agreeing that its asteroid target (1998 SF36) meets the SSB classification for a body from which a Category V mission with "unrestricted Earth-return" is warranted."

Beagle-2 Presentation and Discussion

With the assistance of Dr. Judith Pillinger of the United Kingdom, the Workshop was given a presentation on the planetary protection provisions for the upcoming Beagle-2 lander mission (Appendix E). There was some discussion, and the Workshop consensus is that Beagle-2 is compliant with the policy provisions being recommended by the Workshop report. Dr. Gerhard Schwehm informed the group that the European Space Agency (ESA) has planned a review of planetary protection for Beagle-2 in May of 2002.

Requirements for Human Missions to Mars:Plenary Discussion

The Workshop in plenary undertook a discussion of the planetary protection implications of future human missions to Mars, and used as a starting point the US National Research Council (NRC) / Space Studies Board report on Biological Contamination of Mars (Space Studies Board 1992). The group agreed with the Report's recommendation that noted the importance of a series of robotic precursor missions prior to any human missions to Mars. An open discussion considered three categories of issues associated with human exploration—contamination of Mars, contamination or hazards for astronauts, and potential contamination or hazards upon return to Earth. While there is clearly a need for further research and development, prior to any human missions, the group agreed that:

- Robotic missions, including sample return, must precede human missions to provide important scientific information about the planet, potential life or biohazards, and other data critical to eventual human exploration
- Special regions on Mars must be protected from human-associated terrestrial contamination both during robotic and human exploration
- During human missions, all activities and operations must be done in a way that continues to protect Mars as a location for future biological exploration
- The Apollo experience and other pertinent reports (national and international) should be re-examined in detail for 'lessons learned' and lessons to be applied to human Mars missions
- Considerations about terraforming or proposed large-scale changes to the martian environment must be restricted until considerably more information is available from *in situ* robotic missions, sample return, and human exploration.

In addition, the following specific research and engineering topics were discussed in some detail:

- Robotic precursor missions will be important for gathering data useful for future human missions. In particular, it will be important to study martian dusts to determine the extent to which they may or may not be a biohazard, and whether they may be pre-certified as 'safe' and not containing martian life. If martian dusts are devoid of life or sterile, they may be non-significant as a cross contamination concern.
- It will be important to consider the future intentional propagation of biological Earth materials on Mars (for food, life support, etc.), with special consideration for how they will

be contained, used and/or disposed, both while attended by humans, and during periods when they may be unattended (after human departure?)

In advance of human missions, critical engineering development tasks with planetary protection implications include:

- Design a completely contained system which isolates terrestrial and human associated materials of biological concern from the martian environment
- Design systems that will enable utilization of martian resources without contaminating special regions on Mars
- Design systems that would appropriately break the chain of contact with the martian environment for returning human astronauts who have been in contact with martian materials.

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COSPAR PLANETARY PROTECTION POLICY
DRAFT TO BE PRESENTED TO THE COUNCIL AND BUREAU FOR CONSIDERATION
(Prepared by the COSPAR/IAU Workshop on Planetary Protection, April, 2002)

PREAMBLE

Noting that COSPAR has concerned itself with questions of biological contamination and spaceflight since its very inception, and
noting that Article IX of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (also known as the UN Space Treaty of 1967) states that:

> States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter, and where necessary, shall adopt appropriate measures for this purpose. (UN 1967)

therefore, COSPAR maintains and promulgates this planetary protection policy for the reference of spacefaring nations, both as an international standard on procedures to avoid organic-constituent and biological contamination in space exploration, and to provide accepted guidelines in this area to guide compliance with the wording of this UN Space Treaty and other relevant international agreements.

POLICY

COSPAR,
Referring to COSPAR Resolutions 26.5 and 26.7 of 1964, the Report of the Consultative Group on Potentially Harmful Effects of Space Experiments of 1966, the Report of the same Group of 1967, and the Report of the COSPAR/IAU Workshop of 2002,
notes with appreciation and interest the extensive work done by the Panel on Standards for Space probe Sterilization and its successors the Panel on Planetary Quarantine and the Panel on Planetary Protection and
accepts that for certain space mission/target body combinations, controls on contamination shall be imposed in accordance with a specified range of requirements, based on the following policy statement:

> Although the existence of life elsewhere in the solar system may be unlikely, the conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized. In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet. Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed, in accordance with issuances implementing this policy. (DeVincenzi et al. 1983)

The five categories for target body/mission type combinations and their respective suggested ranges of requirements are described as follows, and in Table 1. Assignment of categories for specific mission/body combinations is to be determined by the best multidisciplinary scientific advice. For new determinations not covered by this policy, such advice should be obtained through the auspices of the Member National Scientific Institutions of COSPAR. In case such advice is not available, COSPAR will consider providing such advice through an *ad hoc* multidisciplinary committee formed in consultation with its Member National Scientific Institutions and International Scientific Unions:

Category I includes any mission to a target body which is not of direct interest for understanding the process of chemical evolution or the origin of life. No protection of such bodies is warranted and no planetary protection requirements are imposed by this policy.

Category II missions comprise all types of missions to those target bodies where there is significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote chance that contamination carried by a spacecraft could jeopardize future exploration. The requirements are for simple documentation only. Preparation of a short planetary protection plan is required for these flight projects primarily to outline intended or potential impact targets, brief Pre- and Post-launch analyses detailing impact strategies, and a Post-encounter and End-of-Mission Report which will provide the location of impact if such an event occurs. Solar system bodies considered to be classified as Category II are listed in the Appendix to this document.

Category III missions comprise certain types of missions (mostly flyby and orbiter) to a target body of chemical evolution and/or origin of life interest or for which scientific opinion provides a significant chance of contamination which could jeopardize a future biological experiment. Requirements will consist of documentation (more involved than Category II) and some implementing procedures, including trajectory biasing, the use of cleanrooms during spacecraft assembly and testing, and possibly bioburden reduction. Although no impact is intended for Category III missions, an inventory of bulk constituent organics is required if the probability of impact is significant. Category III specifications for selected solar system bodies are set forth in the Appendix to this document. Solar system bodies considered to be classified as Category III also are listed in the Appendix.

Category IV missions comprise certain types of missions (mostly probe and lander) to a target body of chemical evolution and/or origin of life interest or for which scientific opinion provides a significant chance of contamination which could jeopardize future biological experiments. Requirements imposed include rather detailed documentation (more involved than Category III), including a bioassay to enumerate the bioburden, a probability of contamination analysis, an inventory of the bulk constituent organics and an increased number of implementing procedures. The implementing procedures required may include trajectory biasing, cleanrooms, bioload reduction, possible partial sterilization of the direct contact hardware and a bioshield for that hardware. Generally, the requirements and compliance are similar to *Viking*, with the exception of complete lander/probe sterilization. Category IV specifications for selected solar system bodies are set forth in the Appendix to this document. Solar system bodies considered to be classified as Category IV also are listed in the Appendix.

Category V missions comprise all Earth-return missions. The concern for these missions is the protection of the terrestrial system, the Earth and the Moon. (The Moon must be protected from back contamination to retain freedom from planetary protection requirements on Earth-Moon travel.) For solar system bodies deemed by scientific opinion to have no indigenous life forms, a subcategory "unrestricted Earth return" is defined. Missions in this subcategory have planetary protection requirements on the outbound phase only, corresponding to the category of that phase (typically Category I or II). For all other Category V missions, in a subcategory defined as "restricted Earth return," the highest degree of concern is expressed by the absolute prohibition of destructive impact upon return, the need for containment throughout the return phase of all returned hardware which directly contacted the target body or unsterilized material from the body, and the need for containment of any unsterilized sample collected and returned to Earth. Post-mission, there is a need to conduct timely analyses of the unsterilized sample collected and returned to Earth, under strict containment, and using the most sensitive techniques. If any sign of the existence of a nonterrestrial replicating entity is found, the returned sample must remain contained unless treated by an effective sterilizing procedure. Category V concerns are reflected in requirements that encompass those of Category IV plus a continuing monitoring of project activities, studies and research (i.e., in sterilization procedures and containment techniques).

Further, COSPAR

Recommends that, in order to meet this objective, members provide information to COSPAR within a reasonable time not to exceed six months after launch about the procedures and computations used for each flight and again within one year after the end of a solar-system exploration mission about the success of the mission. COSPAR will maintain a repository of these reports, make them available to the public, and annually deliver a record of these reports to the Secretary General of the United Nations.

Reports should include, but not be limited to, the following information:

1. The estimated biological burden at launch, the methods used to obtain the estimate (e.g., assay techniques applied to spacecraft or a proxy), and the statistical uncertainty in the estimate.

2. The probable composition (identification) of the biological burden for Category IV missions, and for Category V "restricted Earth return" missions.

3. Methods used to control the biological burden, decontaminate and/or sterilize the space flight hardware.

4. The organic inventory of all impacting or landed spacecraft or spacecraft-components, for quantities exceeding 1 kg.

5. Intended minimum distance from the surface of the target body for launched components, for those vehicles not intended to land on the body.

6. Approximate orbital parameters, expected or realized, for any vehicle which is intended to be placed in orbit around a solar system body.

7. For the end-of-mission, the disposition of the spacecraft and all of its major components, either in space or for landed components by position (or estimated position) on a planetary surface.

(COSPAR 1969, 1984, 1994; Rummel et al. 2002)

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Table 1. Proposed Categories for Solar System Bodies and Types of Missions (DeVincenzi et al. 1983, 1994; COSPAR 1984, 1994; Rummel et al. 2002)

	Category I	Category II	Category III	Category IV	Category V
Type of Mission	Any but Earth Return	Any but Earth Return	No direct contact (flyby, some orbiters)	Direct contact (lander, probe, some orbiters)	Earth return
Target Body	See Appendix	See Appendix	See Appendix	See Appendix	See Appendix
Degree of Concern	None	Record of planned impact probability and contamination control measures	Limit on impact probability Passive bioload control	Limit on probability of non-nominal impact Limit on bioload (active control)	If restricted Earth return: • No impact on Earth or Moon; • Returned hardware sterile; • Containment of any sample.
Representative Range of Requirements	None	Documentation only (all brief): • PP plan • Pre-launch report • Post-launch report • Post-encounter report • End-of-mission report	Documentation (Category II plus) • Contamination control • Organics inventory (as necessary) Implementing procedures such as: • Trajectory biasing • Cleanroom • Bioload reduction (as necessary)	Documentation (Category II plus) • P_c analysis plan • Microbial reduction plan • Microbial assay plan • Organics inventory Implementing procedures such as: • Trajectory biasing • Cleanroom • Bioload reduction • Partial sterilization of contacting hardware (as necessary) • Bioshield Monitoring of bioload via bioassay	*Outbound* Same category as target body/ outbound mission *Inbound* If restricted Earth return: • Documentation (Category II plus) • P_c analysis plan • Microbial reduction plan • Microbial assay plan • Trajectory biasing • Sterile or contained returned hardware • Continual monitoring of project activities • Project advanced studies/research. If unrestricted Earth return: • None

APPENDIX: IMPLEMENTATION GUIDELINES AND CATEGORY SPECIFICATIONS FOR INDIVIDUAL TARGET BODIES (Version April 4, 2002)

Implementation Guidelines on the Use of Clean-Room Technology for Outer-Planet Missions

COSPAR,

Noting that in the exploration of the outer planets, the probabilities of growth of contaminating terrestrial micro-organisms are extremely low, reflecting the fact that the environments of these planets appear hostile to all known biological processes,

noting also that these environments do not preclude the possibility of *indigenous* life forms in some of these environments,

recognizing that the search for life is a potentially valid objective in the exploration of the outer solar system,

recognizing that the organic chemistry of these bodies remains of paramount importance to our understanding of the process of chemical evolution and its relationship to the origin of life,

recognizing that study of the processes of the pre-biotic organic syntheses under natural conditions must not be jeopardized,

recommends the use of the best available clean-room technology, comparable with that employed for the *Viking* mission, for all missions to the outer planets and their satellites. (COSPAR 1976)

Implementation Guidelines for Category V Missions

If during the course of a Category V mission there is a change in the circumstances that led to its classification, or a mission failure, e.g.:

- New data or scientific opinion arise that would lead to the reclassification of a mission classified as "Unrestricted Earth return" to "Restricted Earth return," and safe return of the sample cannot be assured, OR
- The sample containment system of a mission classified as "Restricted Earth return" is thought to be compromised, and sample sterilization is impossible,

then the sample to be returned shall be abandoned, and if already collected the spacecraft carrying the sample must not be allowed to return to the Earth or the Moon.

Category-Specific Listing of Target Body/Mission Types

Category I: Flyby, Orbiter, Lander: Venus; Undifferentiated, metamorphosed asteroids; others TBD

Category II: Flyby, Orbiter, Lander: Comets; Carbonaceous Chondrite Asteroids; Jupiter; Saturn; Uranus; Neptune; Pluto/Charon; Kuiper-Belt Objects; others TBD

Category III: Flyby, Orbiters: Mars; Europa; others TBD

Category IV: Lander Missions: Mars; Europa; others TBD

Category V: Any Earth-return mission. "Restricted Earth return": Mars; Europa; others TBD

CATEGORY III/IV/V REQUIREMENTS FOR MARS

Missions to Mars

Category III. Mars orbiters will not be required to meet orbital lifetime requirements* if they achieve bioburden levels equivalent to the *Viking* lander pre-sterilization total bioburden. (*Defined as 20 years after launch at greater than or equal to 99% probability, and 50 years after launch at greater than or equal to 95% probability.) (DeVincenzi et al. 1994)

Category IV for Mars is subdivided into IVa, IVb, and IVc:

Category IVa. Lander systems not carrying instruments for the investigations of extant martian life are restricted to a biological burden no greater than *Viking* lander pre-sterilization levels

Category IVb. For lander systems designed to investigate extant martian life, all of the requirements of Category IVa apply, along with the following requirement:

- The entire landed system must be sterilized at least to *Viking* post-sterilization biological burden levels, or to levels of biological burden reduction driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent

OR

- The subsystems which are involved in the acquisition, delivery, and analysis of samples used for life detection must be sterilized to these levels, and a method of preventing recontamination of the sterilized subsystems and the contamination of the material to be analyzed is in place.

Category IVc. For missions which investigate martian special regions (see definition below), even if they do not include life detection experiments, all of the requirements of Category IVa apply, along with the following requirement:

- Case 1. If the landing site is within the special region, the entire landed system shall be sterilized at least to the *Viking* post-sterilization biological burden levels.
- Case 2. If the special region is accessed though horizontal or vertical mobility, either the entire landed system shall be sterilized to the *Viking* post-sterilization biological burden levels, **OR** the subsystems which directly contact the special region shall be sterilized to these levels, and a method of preventing their recontamination prior to accessing the special region shall be provided.

If an off-nominal condition (such as a hard landing) would cause a high probability of inadvertent biological contamination of the special region by the spacecraft, the entire landed system must be sterilized to the *Viking* post-sterilization biological burden levels.

Definition of "Special Region"

A Special Region is defined as a region within which terrestrial organisms are likely to propagate, **OR** a region which is interpreted to have a high potential for the existence of extant martian life forms.

Given current understanding, this is apply to regions where liquid water is present or may occur. Specific examples include but are not limited to:

- Subsurface access in an area and to a depth where the presence of liquid water is probable
- Penetrations into the polar caps
- Areas of hydrothermal activity.

Sample Return Missions from Mars

Category V. The Earth return mission is classified, "Restricted Earth return."

- Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later Mars missions.
- The sample container must be sealed after sample acquisition. A redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required. The integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.
- The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars. No uncontained hardware that contacted Mars, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the Mars environment shall be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.
- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth re-entry.
- A program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

CATEGORY III/IV/V REQUIREMENTS FOR EUROPA

Missions to Europa

Category III and IV. Requirements for Europa flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of an europan ocean to less than 1×10^{-4} per mission. These requirements will be refined in future years, but the calculation of this probability should include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

- Bioburden at launch
- Cruise survival for contaminating organisms
- Organism survival in the radiation environment adjacent to Europa
- Probability of landing on Europa
- The mechanisms of transport to the europan subsurface
- Organism survival and proliferation before, during, and after subsurface transfer

Preliminary calculations of the probability of contamination suggest that bioburden reduction will likely be necessary even for Europa orbiters (Category III) as well as for landers, requiring the use of cleanroom technology and the cleanliness of all parts before assembly, and the monitoring of spacecraft assembly facilities to understand the bioload and its microbial diversity, including specific problematic species. Specific methods should be developed to eradicate problematic species. Methods of bioburden reduction should reflect the type of environments found on Europa, focusing on Earth extremophiles most likely to survive on Europa, such as cold and radiation tolerant organisms (SSB 2000).

Sample Return Missions from Europa

Category V. The Earth return mission is classified, "Restricted Earth return."

- The outbound leg of the mission shall meet the contamination control requirements given above. This provision should avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned.
- The sample container must be sealed after sample acquisition. A redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required. The integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.
- The mission and the spacecraft design must provide a method to "break the chain of contact" with Europa. No uncontained hardware that contacted Europa, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the europan environment shall be provided during sample container loading into the containment system, launch from Europa, and any in-flight transfer operations required by the mission.
- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Europa or the europan environment for return to Earth; and 3) prior to commitment to Earth re-entry.
- A program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample (SSB 1998).

CATEGORY REQUIREMENTS FOR SMALL SOLAR SYSTEM BODIES

Missions to Small Solar System Bodies

Category I, II, III, or IV. The small bodies of the solar system not elsewhere discussed in this policy represent a very large class of objects. Imposing forward contamination controls on these missions is not warranted except on a case-by-case basis, so most such missions should reflect Categories I or II. Further elaboration of this requirement is anticipated.

Sample Return Missions from Small Solar System Bodies

Category V. Determination as to whether a mission is classified "Restricted Earth return" or not shall be undertaken with respect to the best multidisciplinary scientific advice, using the framework presented in the 1998 report of the US National Research Council's Space Studies Board entitled, *Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making* (SSB 1998). Specifically, such a determination shall address the following six questions for each body intended to be sampled:

1. Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?
2. Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?
3. Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO2 or carbonates and an appropriate source of reducing equivalents) in or on the target body to support life?
4. Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160°C)?
5. Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?
6. Does the preponderance of scientific evidence indicate that there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

For containment procedures to be necessary ("Restricted Earth return"), an answer of "no" or "uncertain" needs to be returned to all six questions.

For missions determined to be Category V, "Restricted Earth return," the following requirements shall be met:

- The outbound leg of the mission shall meet contamination control requirements to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in any search for life in the sample after it is returned.
- The sample container must be sealed after sample acquisition. A redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required. The integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.
- The mission and the spacecraft design must provide a method to "break the chain of contact" with the small body. No uncontained hardware that contacted the body, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the body's

environment shall be provided during sample container loading into the containment system, launch from the body, and any in-flight transfer operations required by the mission.

- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving the body or its environment for return to Earth; and 3) prior to commitment to Earth re-entry.
- A program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample (SSB 1998).

Appendix A

AGENDA

COSPAR/IAU Planetary Protection Workshop
April 2 – 4, 2002

Tuesday – April 2, 2002

8:00 a.m.	**Breakfast**	Berkeley Room Foyer
9:00 a.m.	**Plenary Session:** Introductions and Overview COSPAR Policy and Its Background - History - Processing Changes - Current Status and Plans	Berkeley Room
10:15 a.m.	**Plenary: Workshop Objectives and Plan**	Berkeley Room
10:45 a.m.	**Break**	
11:15 a.m.	**Plenary: Recent Recommendations / Activities in Planetary Protection**	Berkeley Room
12:30 p.m.	**Lunch**	Papillon - Bistro
1:30 p.m.	**Plenary:** **Small Group Assignments and Briefs** - Policy Process/Implementation - Mars - Europa - Small Bodies	 Berkeley Room Yorktown Parlor Williamsburg Parlor Jamestown Parlor
2:00 p.m.	**Small Group Discussions** Topics - Policy Process/Implementation - Mars - Europa - Small Bodies	 Berkeley Room Yorktown Parlor Williamsburg Parlor Jamestown Parlor
3:15 p.m.	**Break**	
3:30 p.m.	**Small Group Discussions (continued)** - Policy Process/Implementation - Mars - Europa - Small Bodies	 Berkeley Room Yorktown Parlor Williamsburg Parlor Jamestown Parlor
4:30 p.m.	**Plenary** Status of Small Groups	Berkeley Room
5:15 p.m.	**Small Group Discussions and Assignments**	Breakout Rooms
5:45 p.m.	**Adjourn**	
6:00 p.m.	**Reception**	Patio or Gloucester Room

Appendix A (cont.):

AGENDA

COSPAR/IAU Planetary Protection Workshop
April 2 – 4, 2002

Wednesday – April 3, 2002

8:00 a.m.	**Breakfast**	Berkeley Room Foyer
9:00 a.m.	**Small Group Discussions Continue** Topics - Policy Process/Implementation - Mars - Europa - Small Bodies	 Berkeley Room Yorktown Parlor Williamsburg Parlor Jamestown Parlor
10:30 a.m.	**Break**	
10:45 a.m.	Small Group Discussions Continue Summaries and Report Preparation - Policy Process/Implementation - Mars - Europa - Small Bodies	 Berkeley Room Yorktown Parlor Williamsburg Parlor Jamestown Parlor
12:30 p.m.	**Lunch**	Papillon Bistro
1:30 p.m.	**Plenary Session: Small Group Reports** Topics - Policy Process/Implementation - Mars - Europa - Small Bodies	Berkeley Room
2:30 p. m.	**Plenary Session** International Standards and a COSPAR Policy Document/WSC Resolutions Discussion	Berkeley Room
3:15 p.m.	**Break**	
3:30 p.m.	**Plenary Session: MUSES-C** Presentation/Categorization Discussion	Berkeley Room
4:30 p.m.	**Plenary Continues** MUSES-C	Berkeley Room
5:00 p.m.	**Adjourn**	

Appendix A (cont.):

AGENDA

COSPAR/IAU Planetary Protection Workshop
April 2 – 4, 2002

Thursday– April 4, 2002

8:00 a.m.	**Breakfast**	Berkeley Room Foyer
9:00 a.m.	**Plenary** Finalize WSC Resolution(s)	Berkeley Room
10:15 a.m.	**Plenary** Emerging Issues in Planetary Protection - Mars Forward/ Backward Contamination - Small-Body Sample Return - Europa and the Outer Planets - Human Exploration Discussion	Berkeley Room
11:00 a.m.	Plenary COSPAR Planetary Protection Panel Planning	Berkeley Room
12:30 p.m.	**Lunch**	Papillon Bistro
1:30 p.m.	**Adjourn**	

Appendix B: Subgroup Charters and Assignments

COSPAR/IAU Planetary Protection Workshop
Williamsburg, Virginia, USA
2-4 April 2002

Subgroup 1 Mars:

Current COSPAR Policy for Mars reflects the recommendations of the 1992 Space Studies Board report on the forward contamination of Mars. Assess the adequacy of the Space Studies Board's report on Mars back contamination issues, and propose wording to include appropriate facets of those recommendations in the proposed integrated COSPAR policy and guidelines. Regarding the forward contamination of Mars, are the requirements, as they now exist, sufficient, complete, and representative of the current state of knowledge about Mars? If deemed necessary, propose wording for the integrated COSPAR policy and guidelines.

Judith Allton	
Jack Barengoltz	
David Beaty	
Alain Berinstain	
Laura E. Newlin	
Pericles D. Stabekis	Chair
Total Members	6

Subgroup 2 Europa:

Based on the Space Studies Board's report on Europa and current knowledge of the planetary body, what general guidelines should be added to the COSPAR integrated policy to adequately address the prevention of contamination of Europa by Earth organisms? As a minimum, what category should be assigned to Europa-bound spacecraft? Regarding the issue of back contamination, what should be the classification for a Europa sample return mission?

Carleton C. Allen	
Sheryl Bergstrom	
Natalia Gontareva	
Gerda Horneck	Chair
Michael A. Meyer	
Mike Thornton	
Kasthuri Venkateswaran	
Norman Wainwright	
Total Members	8

Subgroup 3 Small Bodies:

Based on the Space Studies Board's (SSB) report on small bodies and other pertinent information, propose guidelines that should be added to the integrated COSPAR policy to assure that small bodies are protected from forward contamination and Earth from the potential for back contamination during small-body sample return? Should the framework suggested by the SSB report (i.e., the six parameters that address the question of indigenous life and the three categories of recommendations on containment) be adopted as an integral part of the COSPAR integrated party, and how? What, if any, are the concerns regarding the forward contamination of small bodies?

Michael A'Hearn	
David Boughey	
Donald DeVincenzi	Chair
Akira Fujiwara	
Jun'ichiro Kawaguchi	
Margaret Race	
Gerhard Schwehm	
Kuninori Uesugi	
Total Members	7

Subgroup 4 Policy Process/Implementation

The proposed integrated COSPAR policy and guidelines attempt to consolidate planetary protection requirements. At what level should the implementation requirements for the COSPAR policy be embodied in the policy itself, and where should latitude be available to mission implementers? In order to allow for the updating and application of the COSPAR policy, the most recent scientific opinion about a target body or bodies is essential. Who should be tasked to provide that opinion for 1) national, and 2) international exploration missions? What should be the requirements for member-states to report on planetary protection provisions adopted? What steps should the COSPAR Planetary Protection Panel undertake to assure that the standards promulgated by COSPAR are international in scope, evenly applied, effectively implemented, and known to all interested parties?

Sandra M. Dawson	
Mikhail Ivanov	
Michèle Régimbald-Krnel	Co-Chair
John D. Rummel	Co-Chair
Patricia Sterns	
Michel Viso	
Total Members	7

Appendix C: Presentation by Pericles Stabekis

COSPAR Policy and Background:

History and Processing of Changes

COSPAR/IAU Planetary Protection Workshop
April 2-4, 2002
Williamsburg, VA

Pericles D. Stabekis
Windermere
Washington, D.C.

Historical Background

1956 The International Astronautical Federation (IAF) at its VIIth Congress in Rome attempts to coordinate international efforts to prevent interplanetary contamination. This leads to the formation of the International Institute of Space Law.

1956 Initial attempts to deal with contamination and sterilization issues were also carried out by the United Nations Committee on the Peaceful uses of Outer Space (UNCOPUOS).

1957 The U.S. National Academy of Sciences (NAS) expresses concerns with the problems of interplanetary contamination resulting from space exploration. Urges that lunar and planetary studies be carried out so as to prevent contamination. Requests the International Council of Scientific Unions (ICSU) to assist in the evaluation of the possibilities of such contamination and in the development of means to prevent it.

Historical Background
(Continued)

1958 The ICSU establishes an *ad hoc* Committee on Contamination by Extraterrestrial Exploration (CETEX). CETEX provides preliminary findings regarding the possible contamination of the moon, Mars, and Venus and recommends the establishment of a code of conduct for space missions and research.

1958 ICSU accepts the CETEX recommendations and establishes the Committee on Space Research (COSPAR) to coordinate worldwide space research.

1958 The NAS forms the Space Science Board (SSB), which, among other duties, was charged with addressing, and providing advice on issues of interplanetary contamination.

Historical Background
(Continued)

1959 The SSB reviews the CETEX report and recommends sterilization of space probes. Endorses CETEX recommendations regarding code of conduct and the formation COSPAR.

1960 Several studies were initiated on the probability of contaminating the moon, Mars and Venus.

1961 ICSU adopts resolution 10 "Space Experiments with Undesirable Effects" which recommends that all countries launching space experiments that could have an adverse effect on other scientific research should provide the ICSU and COSPAR with the information necessary to evaluate the potential contamination.

1962 COSPAR organizes a Consultative Group on Potentially Harmful Effects of Space Experiments to help conduct these evaluations.

Historical Background
(Continued)

1963 On the basis of extensive studies and the advice of the SSB, NASA adopts the following policy regarding the moon, Mars and Venus: lunar spacecraft will reduce their microbial load to a "minimum" through the use of assembly and check out in clean rooms and the application of surface sterilants after final assembly and check out; Mars flights will have less than 10^{-4} probability of hitting the planet, while landers would be sterilized after complete assembly and check out, using appropriate procedures and sealed units that would not be open; Venus flights will have less than 10^{-2} probability of hitting the planet.

1964 COSPAR adopts resolution 26.5 which establishes a quantitative framework for the development of planetary protection standards. This framework would last until 1982.

COSPAR PLANETARY PROTECTION RESOLUTIONS
COSPAR RESOLUTION 26.5
COSPAR Information Bulletin No. 20, 1964, p. 25-26

COSPAR "*accepts*, as tentatively recommended interim objectives, a sterilization level such that the probability of a single viable organism aboard any spacecraft intended for planetary landing or atmospheric penetration would be less than $1x10^{-4}$, and a probability limit for accidental planetary impact by unsterilized fly-by or orbiting spacecraft of $3x10^{-5}$ or less."

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)
PART I

TREATY OF PRINCIPLES GOVERNING THE ACTIVITIES OF STATES IN THE EXPLORATION AND USE OF OUTER SPACE, INCLUDING THE MOON AND OTHER CELESTIAL BODIES

COSPAR Information Bulletin No. 38, June 1967, p. 3-10

"States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter, and where necessary, shall adopt appropriate measures for this purpose."

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)

COSPAR DECISION No. 16

COSPAR Information Bulletin No. 50, July 1969, p.15-16

COSPAR,

referring to COSPAR Resolutions 26.5 and 26.7 of 1964, the Report of the Consultative Group on Potentially Harmful Effects of Space Experiments of 1966, and the Report of the same Group of 1967,

notes with appreciation and interest the extensive work done by the Panel on Standards for Space probe Sterilization (now the Panel on Planetary Quarantine) and

accepts as the basic objective for planetary quarantine of Mars and other planets deemed important for the investigation of extraterrestrial life, or precursors or remnants thereof, a probability of no more than $1x10^{-3}$ that a planet will be contaminated during the period of biological exploration. The period of biological exploration is assumed to be 20 years ending in 1988, and the number of missions to or near the planets is assumed to be 100. Further COSPAR

recommends that, in order to meet this objective, members provide information to COSPAR within a reasonable time not to exceed six months after launch about the sterilization procedures and computations used for each flight.

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)

COSPAR DECISION No. 14
COSPAR Information Bulletin No. 54, May 1970, p.12

COSPAR *recommends* "that the Jovian planets be treated with the same quarantine requirements (for flybys, orbiters or entry probes) as currently apply to Mars, the requirements be upheld until further information is available."

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)

COSPAR DECISION No. 9/76
COSPAR Information Bulletin No. 76, August 1976, p.14

COSPAR,
noting that in the exploration of the outer planets, the probabilities of growth of contaminating terrestrial micro-organisms are extremely low, reflecting the fact that the environments of these planets appear hostile to all known biological processes,
noting also that these environments do not preclude the possibility of *indigenous* life forms in some of these environments,
recognizing that the search for life is a potentially valid objective in the exploration of the outer solar system,
recognizing that the organic chemistry of these bodies remains of paramount importance to our understanding of the process of chemical evolution and its relationship to the origin of life,
recognizing that study of the processes of the pre-biotic organic syntheses under natural conditions must not be jeopardized,
recommends the use of the best available clean-room technology, comparable with that employed for the Viking mission, for all missions to the outer planets and their satellites.

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)

COSPAR INTERNAL DECISION No. 7/84

COSPAR,

considering that the Workshop on Planetary Protection, meeting on 2 July 1984, has proposed new COSPAR guidelines for planetary protection,

noting that the commitment to protection of planets from biological contamination must be sustained, and

noting that planetary protection guidelines must be responsive to current state of knowledge regarding planets

decides that existing planetary protection guidelines (1964, 1966) be amended as follows: replace "the basic probability of one in one thousand that a planet of biological interest will be contaminated shall be used as the guiding criterion during the period of biological exploration..." with "for certain space mission/target planet combinations, controls on contamination shall be imposed in accordance with a specified range of requirements ...", in five categories as defined by D.L. DeVincenzi et al. Adv. Space Res., 3(8):13 (1983). (See Attachment 1 to the Internal Decisions.)

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)
COSPAR INTERNAL DECISION No. 7/84 (cont.)

Attachment 1 to the 1984 Internal Decisions of COSPAR

(With Reference to Internal Decision 7/84)

New COSPAR Guidelines for Planetary Protection

1. Policy: Replace "The basic probability of one in one thousand that a planet of biological interest will be contaminated shall be used as the guiding criterion during the period of biological exploration..."

   with "For certain space mission/target planet combinations, controls on contamination shall be imposed in accordance with a specified range of requirements ..."

2. Range of requirements: Five categories as defined by D.L. DeVincenzi et al. Adv. Space Res., 3(8):13 (1983) excluding classifications).
3. Classification: Assignment of specific mission/planet combinations to be determined by best multidisciplinary scientific advice.
4. Reporting Requirements Unchanged.

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)
COSPAR DECISION No. 1/94
COSPAR Information Bulletin No. 131, July 1994, p.30

In keeping with the COSPAR Planetary Protection Policy adopted in Graz in 1984, and Noting:

1. That the Space Studies Board of the US National Research Council in 1992 recommended an update to the requirements for Mars planetary protection consistent with our current knowledge of Mars;
2. That, at the 29th meeting of COSPAR in Washington in 1992, a resolution was adopted recommending the study of provisions for implementing planetary protection for mars missions;
3. That a workshop on Mars planetary protection requirements, which included representatives of COSPAR, IUBS, national space agencies, planned Mars projects, and the International Mars Exploration Working Group - held in May 1994, concurred in the following amendment to the provisions implementing the COSPAR policy.

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)
COSPAR DECISION No. 1/94 (cont.)
COSPAR Information Bulletin No. 131, July 1994, p.30

Recommends:

That COSPAR adopt the following amended version, as outlined in DeVincenzi, Stabekis & Barengoltz (1994: Paper F3.5.2):

Category III requirements are refined to include:

Mars orbiters will not be required to meet orbital lifetime requirements* if they achieve bioburden levels equivalent to the Viking lander pre-sterilization total bioburden. (*Now defined as 20 years after launch at greater than or equal to 99% probability, and 50 years after launch at greater than or equal to 95% probability.)

COSPAR PLANETARY PROTECTION RESOLUTIONS
(Continued)
COSPAR DECISION No. 1/94 (cont.)
COSPAR Information Bulletin No. 131, July 1994, p.30

Recommends:

Category IV is subdivided into IVa and IVb with restrictions to be defined as:

IVa - Lander systems not carrying instruments for the investigations of extant Martian life are restricted to a biological burden no greater than Viking lander pre-sterilization levels, and

IVb - Lander systems carrying instruments for the investigation of extant Martian life are required to meet at least Viking lander post-sterilization biological burden levels, or levels of biological burden reduction driven by the nature and sensitivity of the particular life -detection experiments, whichever are more stringent.

COSPAR PLANETARY PROTECTION
PROCESSING CHANGES

PROPOSED CHANGES TO POLICY, GUIDELINES, OR SPECIFIC REQUIREMENTS SHOULD BE BROUGHT FORWARD TO THE COSPAR PLANETARY PROTECTION (PP) PANEL FOR DISCUSSION. SHOULD THERE BE CONSENSUS ON THE PROPOSED CHANGES, A RESOLUTION IS DRAFTED AND, AFTER REVIEW AND APPROVAL BY THE PP PANEL, TAKEN FORWARD TO THE COSPAR COUNCIL. SHOULD THE COUNCIL ACCEPT THE RESOLUTION, IT IS THEN SUBMITTED TO THE COSPAR BUREAU FOR FINAL APPROVAL AND ADOPTION BY COSPAR.

Appendix D: MUSES-C Presentation Materials

National Aeronautics and Space Administration
PLANETARY PROTECTION ADVISORY COMMITTEE
March 18-19, 2002
NASA Headquarters
Washington, DC

MEETING REPORT
(excerpts)

PLANETARY PROTECTION ADVISORY COMMITTEE (PPAC)
March 2002

Dr. Norine E. Noonan, Chair
NSSTC

Dr. John D. Rummel, Executive Secretary
NASA Headquarters

Dr. Ronald M. Atlas
University of Louisville

Dr. Colleen M. Cavanaugh
Harvard University

Dr. Carolyn S. Griner
Spacehab, Inc.

Dr. Debra L. Hunt
Duke University

Dr. John F. Kerridge

Mr. Alan Ladwig
Team Encounter

Dr. Debra G. B. Leonard
Hospital of the University of Pennsylvania

Dr. Eugene H. Levy
Rice University

Dr. Carlé M. Pieters
Brown University

Dr. George S. Robinson, III
Robinson & Associates, Inc.

Dr. Laurie Zoloth
San Francisco State University

Dr. David Klein *(Agency Representative)*
NIH/NIAID

Mr. Richard Orr *(Agency Representative)*
USDA

Dr. Robert F. Wharton *(Agency Representative)*
NSF

Dr. Akira Fujiwara *(Internat'l Representative*
ISAS

Dr. Gerhard Schwehm *(Internat'l Representative)*
ESA

Dr. Michel Viso *(Internat'l Representative)*
CNES

Appendix D (cont.):

MUSES-C: NASA Participation and the Asteroid

Dr. Donald Yeomans from the Jet Propulsion Laboratory (JPL) introduced the MUSES-C mission. Dr. Fujiwara from Japan's Institute of Space and Astronautical Science (ISAS) reviewed the current status of the mission. MUSES-C is an engineering mission to develop key technologies (ion engine, autonomous navigation, sampling, reentry) requisite for future advance sample return missions. It is scheduled to be launched in November/December 2002, and will arrive near the asteroid 1998SF36 in June 2005. The capsule will return to Earth by high-velocity direct reentry from interplanetary space in June 2007. Dr. Fujiwara described the spacecraft configuration, trajectory and return path, and the sampling sequence. The spacecraft hovers about 10 km above the target surface (the "home" position). From this position, it observes the asteroid surface. After some detailed mapping, the spacecraft descends to the asteroid surface. Sampling is made by shooting small projectiles onto the surface and capturing ejecta in a "touch and go" mode. About eight hours before Earth reentry, the sampling capsule separates from the spacecraft and the capsule descends by parachute through the atmosphere. After landing in Australia, the on-board beacons are active for two days. Dr. Fujiwara showed the scientific instruments on the spacecraft and described the sampling device (the most important scientific instrument) in detail. NASA/JPL will be doing ground-based observation of the target asteroid and will provide tracking and navigation assistance by the Deep Space Network (DSN). Ames Research Center (ARC) will test the heat-shield material used for the reentry capsule. Due to the failure of the last launch of the MV rocket, the project was delayed and the targeted asteroid was changed to the present one. Due to this change, the recovery site will be in the Woomera prohibited area in Australia, and the permitting process is underway. With respect to planetary protection issues, "Environmental Australia" (EA) is in charge. According to the NRC/SSB, S-type asteroids are safe in terms of planetary protection. However, this policy has not yet been approved by COSPAR or international policy. Action by AE is expected after the COSPAR planetary protection workshop.

Dr. Yeomans discussed the target asteroid and the science rationale. Asteroids represent the leftover bits and pieces from the inner solar system formation process and detailed measurements would identify the chemical mix and conditions from which the inner planets (including Earth) formed. MUSES-C would determine the link between this asteroid's spectral type and its likely meteorite analog. From radar observations, it has been determined that the surface roughness is comparable with asteroid Eros. Dr. Yeomans compared 1998SF36 to other L and LL chondrites. The MUSES-C target body is a S-type asteroid, most likely similar to L or LL chondrites, the most common asteroid type between Mars and Jupiter. The S class is one of several different classes of asteroids. Earth is being inundated by material from S-type asteroids on a daily basis. MUSES-C would also determine the structure, mass, density, and porosity of this asteroid, thus allowing better mitigation strategies for potential Earth-threatening objects of this spectral type. Dr. Yeomans stated that with respect to the six key SSB questions on parameters for life, the MUSES-C target asteroid is not an object would require containment because there has been a natural influx (via meteorites) of the type of material equivalent to the sample.

Discussion:

The Committee discussed the degree to which the radiation parameter applies to the target asteroid and whether we are looking at a sample material that is the same as natural influx. Dr. Noonan reviewed the framework created by the Academy. The ordinary chondrites are the most abundant material falling on the Earth today. The ordinary chondrites are derived from spectral Type S, and it is reasonable to equate S-type asteroids with ordinary chondritic material. It is highly unlikely that there would be any possibility of life on these bodies. Dr. Orr expressed concern about the criterion related to natural influx. Dr. Noonan clarified that the "equivalent" term in the criterion means spectral or chemical equivalent, not mass equivalent. Dr. Levy observed that although the sample from

Appendix D (cont.):

1998SF36 will be a surface sample as opposed to the deep interior that is characteristic of the natural influx, and one could argue that there is not absolute equivalence, the surface sample has been exposed to intense radiation and meets the other criterion. Dr. Noonan noted that the SSB recommended that samples falling into Category 1B receive closer scrutiny on a case-by-case basis. If measurements indicate that the target asteroid has features other than expected, the Committee could discuss the containment issue in light of all of the data and make a recommendation. Dr. Robinson posed the question: Will the Committee assessments be made on an ethical as well as a pragmatic basis? If so, what are the criteria? Dr. Zoloth stated that there needs to be the development of an ethical response or an ethical language. Dr. Levy agreed that the deliberations of the Committee will be involved with ethical issues. The Committee discussed the NAS framework that was set out in the 1998 report. Dr. Noonan stated that the Academy framework encompasses the uncertainties for a fairly large class of planetary exploration activities. The MUSES-C mission is before the Committee because U.S. investigators are involved. COSPAR will take up the Academy framework at the Williamsburg workshop. Dr. Rummel noted that the uncertainty embodied in the Ib classification was more scientifically oriented rather than ethically oriented. The six questions were applied to each class of bodies, and that is how the Ib classification was established. With respect to the MUSES-C target, we can answer affirmatively to questions 5 and 6; we don't know enough to answer the other questions. Dr. Kerridge suggested the Committee will inevitably get into ethical issues, but that it may not be practical to systematize it. He suggested adopting the framework for scientific issues, and let the ethical issues come up for debate. Dr. Zoloth agreed that the Committee needs to focus on what the scientists think are the troubling issues. Dr. Noonan noted that there is a suite of instruments on board that should provide a wealth of information. If the science team discovers something of concern, there will be a window of time in which discussions on the fate of the spacecraft and the sample could be initiated and concluded. At this point, the Committee was reasonably comfortable that the target body fell into the category that would not require containment (other than for scientific purposes). However, some of the members were concerned that if something is discovered that would necessitate sample containment, the only options available would be to bring it back or not; there would not be a means of acceptable containment. In response to a question, Dr. Fujiwara indicated that before launch, the sample cone would be cleaned, irradiated, and sealed. Since this is not a life-detection mission, there is not a concern with forward contamination.

The Committee discussed the wording of a proposed draft recommendation regarding planetary protection for the MUSES-C mission. The PPAC finalized the recommendation regarding the MUSES-C mission as:

The Committee heard presentations on the MUSES-C mission, and on the nature of the MUSES-C target body, 1998 SF36. We have evaluated the mission for the purpose of assessing planetary protection requirements. Based on the framework presented in *Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making* (NRC 1998), the Committee affirms that the target body belongs to class Ib. After discussion of this mission and the target body, the Committee recommends that no special containment for samples returned from 1998 SF36 is required for the purposes of planetary protection, provided that subsequent information obtained prior to sample return remain consistent with the classification of that body as an undifferentiated metamorphosed asteroid. As such, we recommend that for NASA purposes, the mission be designated Planetary Protection Category V, "unrestricted Earth return."

Appendix D (cont.):

Excerpted table from *"Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies,"* Space Studies Board, US National Academy of Sciences Press, 1998.

TABLE ES.1 Summary of Currently Recommended Approach to Handling Samples Returned from Planetary Satellites and Small Solar System Bodies Assessed by the Task Group on Sample Return from Small Solar System Bodies

I No Special Containment and Handling Warranted Beyond What Is Needed for Scientific Purposes		II Strict Containment and Handling Warranted
Ia High Degree of Confidence	Ib Lesser Degree of Confidence[a]	
The Moon	Phobos	Europa
Io	Deimos	Ganymede
Dynamically new comets[b]	Callisto	P-type asteroids
Interplanetary dust particles[c]	C-type asteroids	D-type asteroids
	Undifferentiated metamorphosed asteroids	Interplanetary dust particles[d]
	Differentiated asteroids	
	All other comets	
	Interplanetary dust particles[e]	

[a]Subcolumn Ib lists those bodies for which confidence in the recommended approach is still high but for which there is insufficient information at present to express it absolutely. This lesser degree of confidence does not mean that containment is warranted for those bodies; rather, it means that continued scrutiny of the issue is warranted for the listed bodies as new data become available. The validity of the task group's conclusion that containment is not warranted for the bodies listed in Ib should be evaluated, on a case-by-case basis, by an appropriately constituted advisory committee in light of the data available at the time that a sample return mission to the body is planned.

[b]Samples from the outer 10 meters of dynamically new comets.

[c]Interplanetary dust particles sampled from the interplanetary medium and from the parent bodies listed in subcolumn Ia.

[d]Interplanetary dust sampled from the parent bodies in column II and collected in a way that would not result in exposure to extreme temperatures.

[e]Interplanetary dust sampled from the parent bodies listed in subcolumn Ib.

Appendix D (cont.):

Extracted from *"Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies,"* Space Studies Board, US National Academy of Sciences Press, 1998.

Six Key Questions
Does the preponderance of evidence indicate that:

Yes (to any question)

No Special Containment

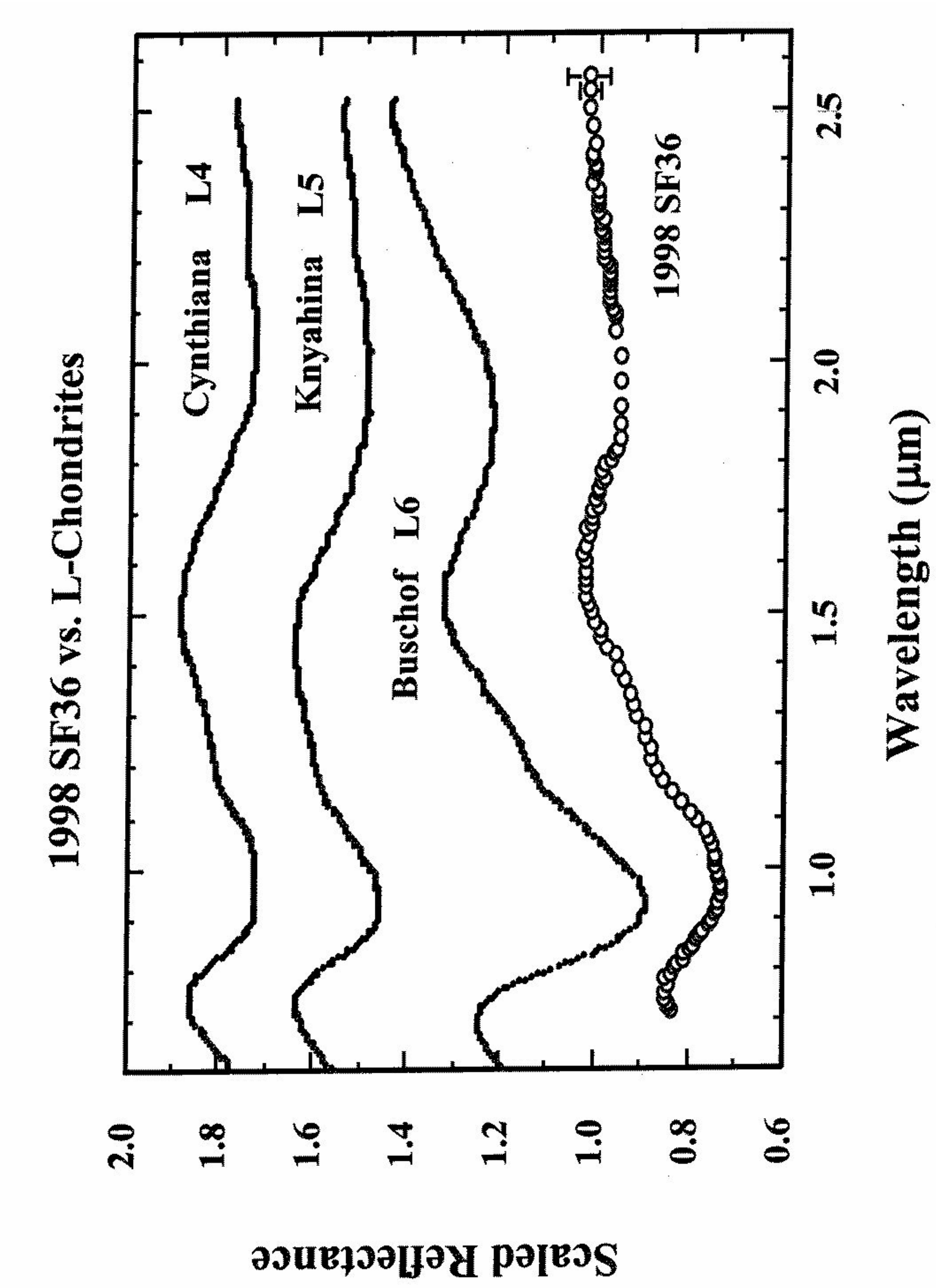
- There was NEVER LIQUID WATER in or on the body?
- METABOLICALLY USEFUL ENERGY SOURCES were NEVER PRESENT?
- There was NEVER SUFFICIENT ORGANIC MATTER (or CO_2 or carbonates and an appropriate source of reducing equivalents) in or on the body to support life?
- SUBSEQUENT TO THE DISAPPEARANCE OF LIQUID WATER, the body has been SUBJECTED TO EXTREME TEMPERATURES (>160℃)
- There is or was SUFFICIENT RADIATION FOR BIOLOGICAL STERILIZATION of terrestrial life forms
- There has been a NATURAL INFLUX TO EARTH of equivalent material from the body

No or Uncertain (to all 6 questions)

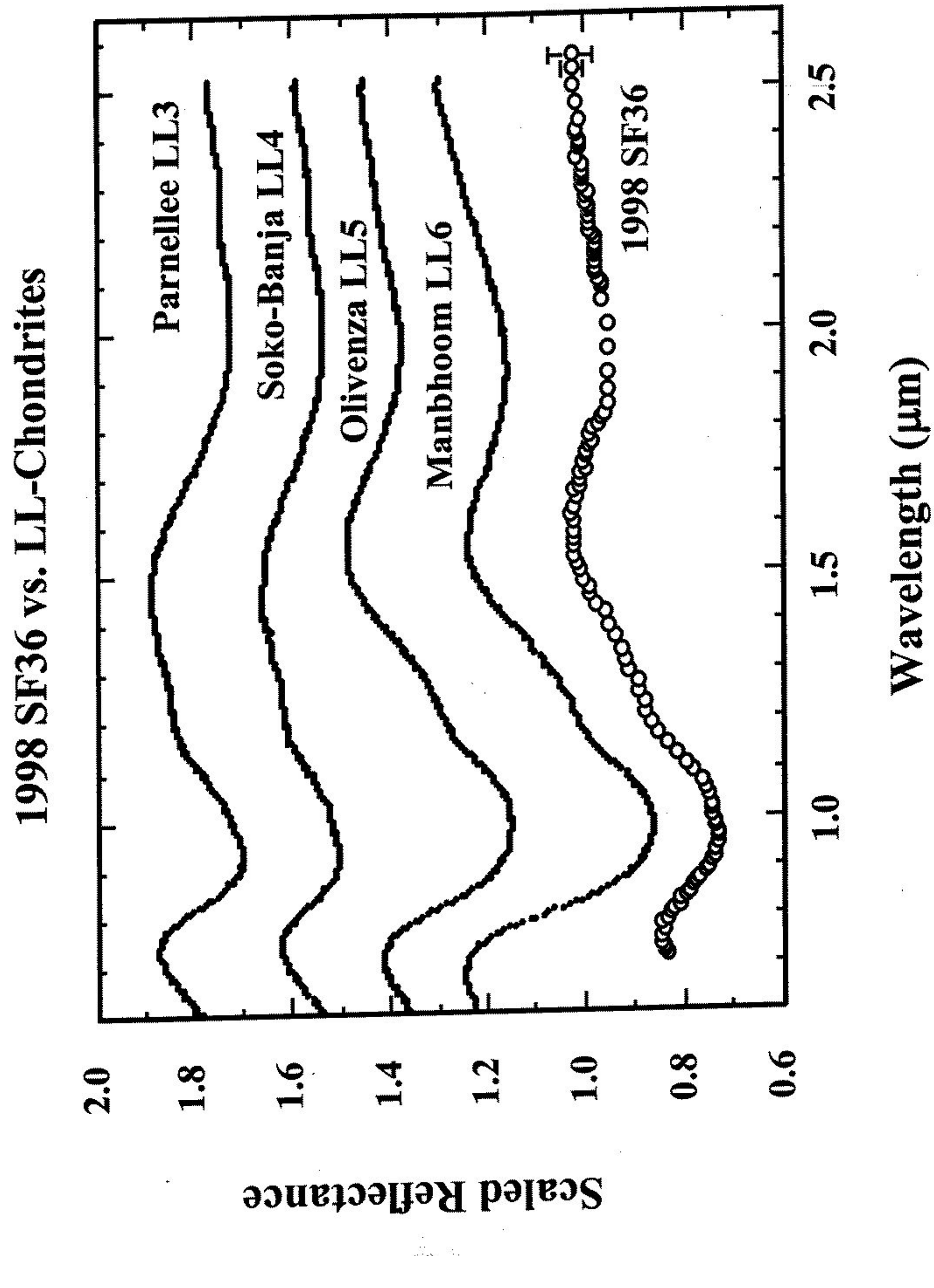
Strict Containment and Handling

Appendix D (cont.):

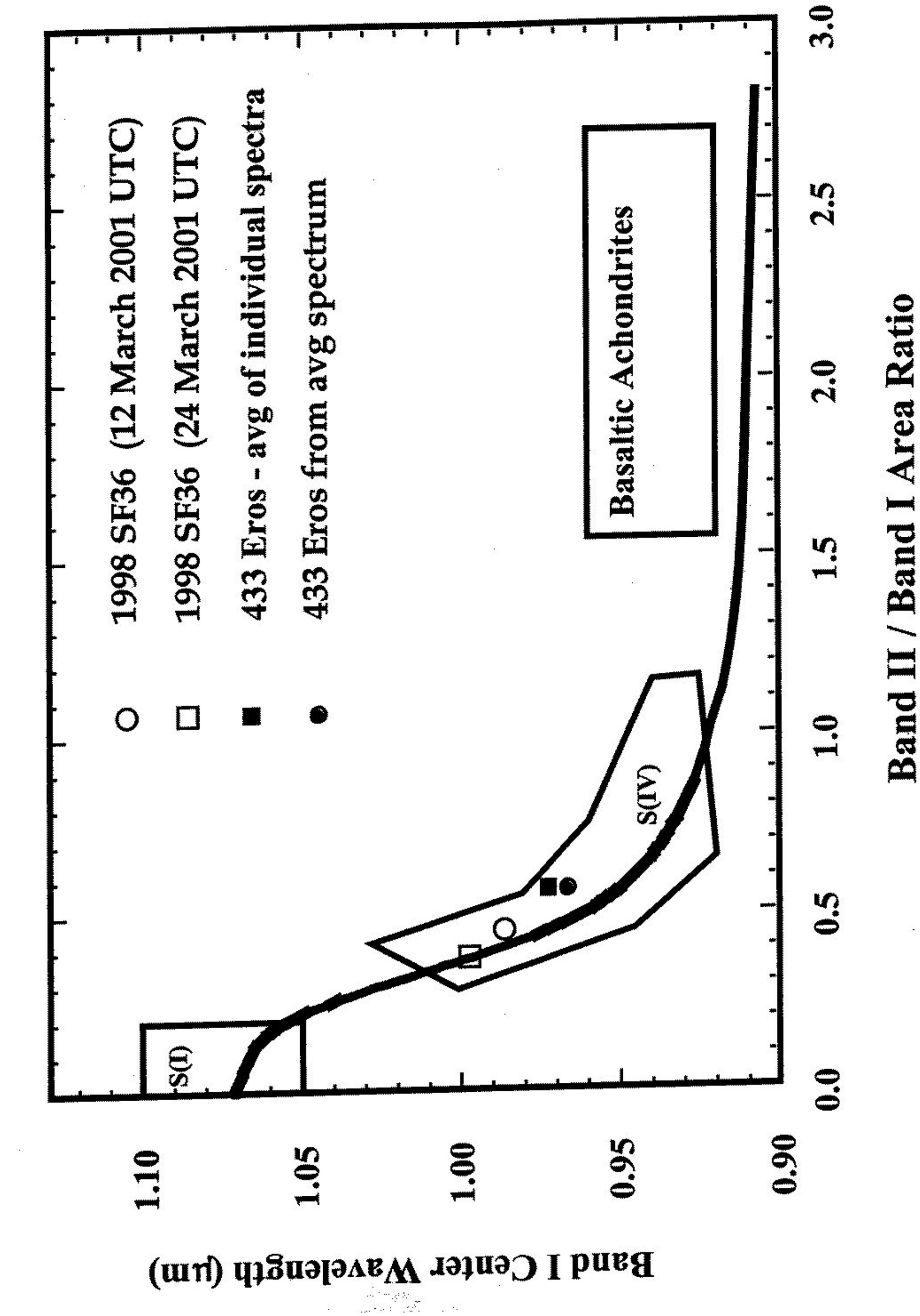
From Presentation by D. Yeomans of JPL to the NASA Planetary Protection Advisory Committee 19 March 2002:



Appendix D (cont.):
From Presentation by D. Yeomans of JPL to the NASA Planetary Protection Advisory Committee 19 March 2002:



Appendix D (cont.):
From Presentation by D. Yeomans of JPL to the NASA Planetary Protection Advisory Committee 19 March 2002:



Appendix D (cont.):

From Presentation by D. Yeomans of JPL to the NASA Planetary Protection Advisory Committee
19 March 2002

Conclusions

- Muses-C target body is a S-type asteroid - most likely similar to L or LL Chondrites.
  - Spectra similar to L or LL Chondrites
  - Color differences also suggest S type asteroid
- Similar conclusions reached by:
  - Kelley et al. (IRTF spectroscopy)
  - Dermawan et al. (U. Tokyo color photometry)
  - Abe et al. (Subaru photometry/spectroscopy)

Appendix E:

Presentation to the COSPAR/IAU Workshop on Planetary Protection, Williamsburg 2-4 April 2002

Beagle 2 Mars

J.M. Pillinger, J.A Spry *, I.P. Wright, S. Sancisi-Frey, J.I. Abbott and C.T. Pillinger

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*** Beagle 2 Planetary Protection Manager**

with thanks to John Rummel for delivering the presentation

Planetary Protection and the approach of the Beagle 2 team

Planetary Protection is of utmost importance to the project. The responsibility for ensuring that the appropriate requirements are met is led by the project Lead Scientist who heads the PP team

Planetary Protection is fundamental to the integrity of the results of the sample analyses from experiments which can detect the presence of carbon containing compounds and indicate biological involvement

The prevention of organic (and inorganic carbon) contamination of those parts of the lander which will contact the samples is paramount. This is a broader (and more difficult) objective than any sterility requirement (as noted by Barengoltz, Adv. Space Res., 2000)

Background - how Beagle 2 will analyse samples

- sample (subsurface soil or rock interior) collected by mole or grinder/corer
- dispensed into gas analysis package
- sample enters selected oven on carousel
- sample heated to predetermined temperature with added oxygen
- gas evolved and purified
- mass spectroscopic analysis
- detection and quantitation of any carbon (and nitrogen) present
- stable isotopic analysis of carbon (and nitrogen)
- repeated as temperature raised incrementally

Background - what Beagle 2 data will show

- presence of carbon - irrespective of the form in which the carbon is found
- temperature of release
- nature of carbon
- quantitation of carbon
- stable carbon isotope ratio
- isotopic fractionation of low temperature fraction (organic) compared to high temperature fraction (inorganic carbonate) indicative of biological reaction
- presence of other elements of biological significance
- presence of trace atmospheric constituents (eg methane)

General issues for small landers and actions taken for Beagle 2

. small components have insufficient surface area for statistically valid total viable count particularly with low levels of contamination

action: materials, manufacturing procedures, handling protocols all examined and recorded and worst case scenario of total bioburden used to determine sterilisation conditions to the maximum sterility assurance level compatible with component integrity

. sterilised components need to be assembled aseptically

action: to ameliorate any recontamination aseptic assembly facility specification and working procedures maintained at highest possible level - full training and basic microbiology teaching for all personnel

. recontamination mostly likely to be from assembly, integration and verification staff

action: monitoring of vegetative, human derived, contaminants in addition to standard assays

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Additional Features for IVa+ over IVa

1. Specific cleaning of vulnerable areas
2. Protection of sampling tools
3. In situ cleaning procedures for sampling tools
4. Full inventory of all materials which could potentially confuse results irrespective of the mass of the material on Beagle 2. Samples of materials will be stored and analysed by laboratory stepped combustion-mass spectrometry methods for both carbon release profile and stable carbon isotopes and nitrogen content.
5. Ultimately blank analyses will be conducted on Mars prior to and following sample analysis.

Appendix E (cont.):

Associated research and method development in progress

- time/temperature survival of microorganisms at extreme temperatures
- effect of dry heat sterilisation of efficacy of surface cleaning methods
- wiping protocols for small areas
- study of attachment of microbes variously deposited onto typical space hardware materials under AIV [IVa?] conditions using SEM and AFM
- evaluation of real time methods for enumeration of viable organisms

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Reporting to COSPAR on Beagle 2

The UK Scientific Society responsible for reporting to COSPAR on Planetary Protection issues is The Royal Society

At the request of the Beagle 2 Lead Scientist, The Royal Society is forming a dedicated committee of Fellows with expertise in microbiology, organic geochemistry, environmental biology, space instrumentation and planetary sciences to review the Beagle 2 Planetary Protection practice

Appendix F:Participants List
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