

| [NODIS Library](#) | [Program Management\(8000s\)](#) | [Search](#) |



# NASA Procedural Requirements

**NPR 8020.12D**

Effective Date: April 20, 2011

Expiration Date: December 20, 2017

**COMPLIANCE IS MANDATORY**

---

## Planetary Protection Provisions for Robotic Extraterrestrial Missions

**Responsible Office: Science Mission Directorate**

## Table of Contents

**SPECIAL ATTENTION: ONLY USE NID 8020.109A: NASA Interim Directive(NID): Planetary Protection Provisions for Robotic Extraterrestrial Missions**, as it is the interim directive to NPR 8020.12D and contains the most recent requirements.

### Change History

- P.2 Applicability
- P.3 Authority
- P.4 Applicable Documents and Forms
- P.5 Measurement/Verification
- P.6 Cancellation

### Chapter 1. Planetary Protection Categorization of Missions

- 1.1 Overview
- 1.2 Relationship to Planetary Flight Project's Project Plan
- 1.3 Deviations

### Chapter 2. General Mission Requirements

- 2.1 NASA Missions
- 2.2 NASA Participation in non-NASA or Missions
- 2.3 Implementation Requirements for U.S. Missions
- 2.4 Monitoring and Verification
- 2.5 Schedules of Documentation and Review Requirements

- 2.6 Deviations
- 2.7 Detailed Documentation Requirements
- 2.8 Detailed Review Requirements
- 2.9 Coordination with Orbital Debris Requirements

## **Chapter 3. Planetary Protection Constraints**

- 3.1 General
- 3.2 Specification of Parameters
- 3.3 Microbiology Related Determinations
- 3.4 Microbial Reduction
- 3.5 Launch and Post-Launch Operations (PP Categories III-V)

## **Chapter 4. Management**

- 4.1 Project Plan
- 4.2 Delegated Responsibilities of the Planetary Protection Officer

## **Chapter 5. Detailed Planetary Protection Requirements**

- 5.1 Numerical Implementation Guidelines for Forward Contamination Calculations not Otherwise Specified
- 5.2 PP Category-Specific Listing of Target Body/Mission Types (advisory only)
- 5.3 PP Category-Specific Requirements for Mars
- 5.4 PP Category II\*/III/IV Requirements for Icy Satellites
- 5.5 Requirements for Small Solar System Bodies
- 5.6 Additional Implementation Guidelines for PP Category V Missions

## **Appendix A. Definitions**

## **Appendix B. Acronyms**

## **Appendix C. Procedural Guidelines for Flight Projects: Communications with the Planetary Protection Officer**

## **Appendix D. Planetary Protection Specification Sheets**

# Preface

## P.1 Purpose

- a. This document sets forth NASA requirements applicable to robotic planetary flight programs. These requirements are necessary to enable the Associate Administrator for the Science Mission Directorate (SMD AA) to fulfill his/her responsibilities pertaining to planetary protection, as required by NPD 8020.7 (Biological Contamination Control for Outbound and Inbound Planetary Spacecraft).
- b. This document specifically addresses: (1) the control of terrestrial microbial contamination associated with robotic space vehicles intended to land, orbit, flyby, or otherwise encounter extraterrestrial solar system bodies, and (2) the control of contamination of the Earth and the Moon by extraterrestrial material collected and returned by robotic missions.

## P.2 Applicability

- a. This NPR is applicable to NASA Headquarters and NASA Centers, including Component Facilities and Technical and Service Support Centers. This language applies to the Jet Propulsion Laboratory, a Federally Funded Research and Development Center, and other contractors, grant recipients, or parties to agreements to the extent specified or referenced in the appropriate contracts, grants, or agreements.
- b. The requirements of this document apply to all robotic missions that may encounter other solar system bodies, including those to and from the Earth's Moon, and to all robotic solar system exploration missions returning extraterrestrial samples to the Earth or the Moon.
- c. This document is specifically not applicable to the following:
  - (1) terrestrial (Earth-orbital) missions.
  - (2) human missions, except for robotic planetary missions launched using manned spacecraft.
- d. NASA officials responsible for applicable flight programs and projects will impose these requirements in such directives or contractual instruments as may be necessary to ensure their implementation.

## P.3 Authority

- a. The National Aeronautics and Space Act, 51 U.S.C. § 20113(a).
- b. NPD 8020.7 Biological Contamination Control for Outbound and Inbound Planetary Spacecraft.

## P.4 Applicable Documents and Forms

- a. NPD 7120.5, NASA Space Flight Program and Project Management Requirements.
- b. NPD 8010.3, Notification of Intent to Decommission or Terminate Operating Space Systems and Terminate Missions.

- c. NPR 8715.6A, NASA Procedural Requirements for Limiting Orbital Debris.
- d. Committee on Space Research (COSPAR) Planetary Protection Policy, as amended.
- e. NASA HDBK 6022, NASA Standard Procedures for the Microbial Examination of Space Hardware (draft).

## **P.5 Measurement/Verification**

- a. To ensure compliance with this NPR, the Planetary Protection Officer (PPO) monitors the planetary protection (PP) -related activities and development of required documentation, specified in this document, by individual missions and approves the final products. Signed and approved documents are to be completed in association with Key Decision Points as described in this document and NPD 7120.5.
- b. Project compliance with requirements described in this NPR is subject to verification by the PPO who is responsible for certifying to the SMD AA, prior to the launch of a planetary mission, that all planetary protection requirements have been met.

## **P.6 Cancellation**

NPR 8020.12C, Planetary Protection Provisions for Robotic Extraterrestrial Missions, dated April 27, 2005.

/S/

E. J. Weiler

Associate Administrator for Science Mission Directorate

# Chapter 1. Planetary Protection

## Categorization of Missions

### 1.1 Overview

1.1.1 Each planetary mission shall be assigned one or more PP categories based on the planetary protection priorities of each extraterrestrial solar system body and the mission plan. Planetary protection priorities and corresponding mission PP categories are given in Table 1. Each PP category has different planetary protection requirements, as described in Chapter 2 of this document. Mission PP categorization is determined by the PPO, upon request from the flight project as specified in section 2.1.2.

Table 1. Mission Planetary Protection Categories

<b>Planetary Target Priority</b>	<b>Mission Type</b>	<b>Mission PP Category</b>
Not of direct interest for understanding the process of chemical evolution or where exploration will not be jeopardized by terrestrial contamination. No protection of such planets is warranted, and no requirements are imposed.	Any	I
Of significant interest relative to the process of chemical evolution but only a remote chance that contamination by spacecraft could compromise future investigations.	Any	II
Of significant interest relative to the process of chemical evolution and/or the origin of life and for which scientific opinion provides a significant chance that contamination by spacecraft could compromise future investigations.	Flyby, Orbiter	III
Of significant interest relative to the process of chemical evolution and/or the origin of life and for which scientific opinion provides a significant chance that contamination by spacecraft could compromise future investigations.	Lander, Probe	IV

Any Solar System Mission	All Earth Return	V Unrestricted Earth Return Restricted Earth Return
--------------------------	------------------	---

**Notes:**

- 1) For missions that target or encounter multiple planets, more than one PP category may be specified for planets targeted or encountered.
- 2) For missions utilizing gravity assist by means of a flyby of another planet, requirements will typically be those for the target requiring the higher degree of protection.

## 1.2 Relationship to Planetary Flight Project's Project Plan

1.2.1 NPD 7120.5, NASA Space Flight Program and Project Management Requirements, requires the preparation of a Project Plan during the formulation of any flight project. The Project Plan shall specify how the project will incorporate any required planetary protection planning. The scope of planetary protection information to be included and the level of detail will vary with each Project Plan. In general, planetary protection planning should be described so as to be consistent with other elements of the Project Plan.

1.2.2 The management approach, a part of each Project Plan, shall include the broad management aspects of the planetary protection activities of the project.

1.2.3 Required planetary protection planning documents, as specified in Chapter 2 of this document, shall be referenced in the Project Plan.

## 1.3 Deviations

1.3.1 The objectives of NASA's planetary protection policy, which is consistent with the policy and guidelines of the Committee on Space Research (COSPAR), shall be met at all times.

1.3.2 Deviations from the specific implementation approaches described in this NPR may be requested, as detailed in section 2.6 of this document. Such requests shall be subject to the review and written approval of the PPO and, when appropriate, by the SMD AA, as specified below.

# Chapter 2. General Mission Requirements

## 2.1 NASA Missions

2.1.1 Specific planetary protection requirements for each planned mission are determined by the NASA PPO, in accordance with this document, and consistent with the policy and guidelines of COSPAR, recommendations of the Space Studies Board (SSB) of the National Research Council (NRC), and advice from the NASA Advisory Council, to the extent appropriate.

2.1.2 Requests for PP categorization of missions and associated mission requirements shall be submitted to the PPO by the mission Project Manager or Principal Investigator before the end of Phase A and, preferably, early during mission design.

2.1.3 Such correspondence shall be accompanied by a mission description that identifies the target object and any other solar system bodies that would be encountered under the proposed spacecraft trajectory, as well as an overview of the proposed operations and end-of-mission scenario. A request and justification for a specific mission PP categorization should be included, and a PP category-specific listing of target body/mission types is provided in Chapter 5 for guidance in preparing this request. The PPO will respond, in writing, with the appropriate PP categorization, conveying such explanatory information or supplemental conditions as may be appropriate.

2.1.4 Documentation required for each mission shall be completed and approved on the schedules given in section 2.5, in coordination with the Key Decision Points (KDPs) described in NPR 7120.5. Approval of a mission's Planetary Protection Plan, for missions above PP Category I, completes formal PP categorization of the mission and should be accomplished no later than the end of Phase B.

## 2.2 NASA Participation in non-NASA Missions

2.2.1 NASA participation in non-NASA missions shall be supported only under the conditions specified.

2.2.1.1 The PP categorization and certification of compliance for the spacecraft shall be the sole responsibility of the lead agency on the mission (that is, the agency designing the mission).

2.2.1.2 When a mission is launched from the United States, documentation of compliance with this NPR's requirements shall be provided to NASA by the lead agency.

2.2.1.3 These activities shall be performed consistent with US obligations under the 1967 Outer Space Treaty.

2.2.2 NASA shall provide hardware, services, data, funding, and other resources to non-NASA missions (including but not limited to resources provided through international agreements, contracts, Space Act agreements, grants, and cooperative agreements) only if the recipient organization(s), whether governmental or private entity, demonstrate adherence to appropriate policies, regulations, and laws regarding planetary protection that are generally consistent with the COSPAR Planetary Protection Policy and Guidelines.

2.2.3 When NASA is providing resources that will be part of a mission on a non-NASA spacecraft, the NASA-supported entity shall submit for approval by the NASA PPO a Planetary Protection Plan and associated documentation, defining the planetary protection requirements to be implemented



and outlining the general procedures to be employed to meet those requirements.

2.2.3.1 A NASA-supported entity anticipating flights on non-NASA spacecraft may receive preliminary guidance by submitting a request to the NASA PPO, outlining its role and details of its role in the anticipated flight opportunity.

2.2.4 When applicable during development and delivery of instruments/experiments, monitoring of the implementation and certification of PP requirements shall be the responsibility of the lead agency (and demonstrated to the launching agency, if different, as part of the launch approval process). The NASA PPO may agree with the lead agency or project to share in or assume such responsibility by separate arrangement.

## **2.3 Implementation Requirements for U.S. Missions**

2.3.1 NASA flight projects shall comply with planetary protection requirements appropriate to the mission PP category provided to them by the PPO. A summary of implementation requirements is provided in Table 2.

A. PP Category I Missions: Certification of a mission as PP Category I relieves a project of all further planetary protection requirements, including further documentation. Solar system missions/bodies classified as PP Category I are listed in Chapter 5.

B. PP Category II Missions: Planetary protection requirements are for documentation only, as detailed in section 2.7. Preparation of a brief Planetary Protection Plan is required for these flight projects in order to state intended or potential impact targets and detailing impact strategies. Projects will also provide Pre-and Post-Launch Reports and an End-of-Mission Report that will provide the location of impact, if such an event occurs. The combinations of solar system bodies and types of missions classified as PP Category II are listed in Chapter 5.

C. PP Category III Missions: Planetary protection requirements consist of documentation as detailed in section 2.7 (generally more involved than PP Category II), review requirements in section 2.8, and some implementing procedures, including trajectory biasing, the use of cleanrooms during spacecraft assembly and testing, and possibly microbial reduction. An inventory of bulk constituent organics is required if the probability of impact is considered significant. The combinations of solar system bodies and types of missions classified as PP Category III are listed in Chapter 5. Detailed requirements and associated specification sheets for PP Category III missions to selected solar system bodies are set forth in Chapter 5 and Appendix D, respectively.

D. PP Category IV Missions: Planetary protection requirements include detailed documentation, listed in Section 2.7 (more involved than PP Category III), review requirements in section 2.8, and also include bioassays to enumerate the microbial burden, a probability of contamination analysis, an inventory of the bulk constituent organics, and an increased number of implementing procedures. These implementing procedures may include trajectory biasing, cleanrooms, microbial reduction, possible partial sterilization of the direct contact hardware and use of biobarriers to protect that hardware from recontamination, and, in some instances, system-level (lander/probe) sterilization. The combinations of solar system bodies and types of missions classified as PP Category IV are listed in Chapter 5. Detailed requirements and associated specification sheets for PP Category IV missions to selected solar system bodies are set forth in Chapter 5 and Appendix D, respectively.

E. PP Category V Missions: This PP category comprises all Earth-return missions. The highest priority for these missions is the protection of the terrestrial system, which includes the Earth



and the Moon. The Moon must be protected from the potential for backward contamination to retain freedom from planetary protection implementation requirements on Earth-Moon travel. PP Category V missions are designated either "Unrestricted Earth Return" for samples from solar system bodies deemed by scientific opinion to have no indigenous life forms; or "Restricted Earth Return" for samples from solar system bodies that may harbor indigenous life. Unrestricted Earth Return missions have PP requirements on the outbound phase only, corresponding to the PP category of that phase (typically PP Category I or II). Restricted Earth Return missions have PP requirements that encompass those for PP Category IV plus the continued monitoring of related project activities, studies, and research. Documentation requirements are detailed in section 2.7, and review requirements in section 2.8. Specific PP Category V requirements for selected solar system bodies are included in Chapter 5.

Table 2. Summary of Planetary Protection Implementation Requirements by Mission PP Category

<b><u>Mission PP Category</u></b>	<b><u>Implementation Requirements</u></b>
I (Any)	Documentation only.
II (Any)	Documentation only.
III (Flyby, Orbiter)	Impact avoidance and/or contamination control including: cleanroom assembly, microbial reduction, and trajectory biasing.
IV (Lander, Probe)	Impact avoidance and contamination control including: cleanroom assembly, microbial reduction, trajectory biasing, organics archiving.
V "Unrestricted Earth Return"	As appropriate for the specified PP category of the outbound mission. No inbound PP requirements.
V "Restricted Earth Return"	Impact avoidance and contamination control including: clean room assembly, microbial containment of sample, breaking chain of contact with target planet, sample containment and biohazard testing in receiving laboratory (continuing monitoring of project activities, preproject advanced studies and research, as needed).

2.3.2 Requests for PP categorization as PP Category V "Unrestricted Earth Return" or "Restricted Earth Return" shall be submitted to the PPO when mission PP categorization is requested. After discussion and review, a memorandum will be submitted by the PPO to the SMD AA requesting the appropriate certification for the sample return portion of the mission. The SMD AA, when appropriate, shall respond with a written certification.

2.3.3 For PP Category V missions designated as "Restricted Earth Return," an extensive set of additional documentation, detailed in section 2.7, shall be required. The associated activities and reviews are intended to ensure that the Earth's biosphere is not adversely affected by the introduction of material from returned samples.

2.3.3.1 The highest degree of concern is expressed by the prohibition of destructive impact upon return, the need for containment throughout the return phase of all returned hardware which directly contacted the target body and/or any unsterilized material from the body, and the need for containment of any unsterilized sample collected and returned to Earth.

2.3.3.2 After the flight mission there is a need to conduct, under strict containment and using approved techniques, timely analyses of the unsterilized sample collected and returned to Earth. If

any sign of a non-terrestrial replicating entity is found, the returned sample must remain contained unless treated by an effective sterilizing procedure.

## 2.4 Monitoring and Verification

2.4.1 The PPO and/or designee, shall have access to technical and programmatic documentation, as well as areas and operations within the project contractor's or supplier's facilities, in which work is performed or items are stored that relate to the project.

2.4.2 The project shall make appropriate arrangements that allow the PPO, and/or designees, to conduct assays on flight hardware and controlled environments, including launch site, during the course of the project.

2.4.3 At the request of the PPO, the project shall make appropriate arrangement that allow the PPO, or designee, to be present during the transport of the bioburden controlled flight hardware and during the launch operations.

## 2.5 Schedules of Documentation and Review Requirements

2.5.1 Planetary protection documents shall be prepared as part of the formal documentation for the project and be submitted via the applicable Program Executive to the PPO for approval. A summary of planning and documentation requirements by mission PP category is presented in Table 3. Detailed information regarding document content is provided in section 2.7.

Table 3. Planning and Documentation Requirements by Mission PP Category

<u>Mission PP Category</u>	<u>Planning and Documentation</u>
I	Certification of PP Category I mission
II	Mission Certification Planetary Protection Plan Pre-Launch Planetary Protection Report Post-Launch Planetary Protection Report (Planetary Protection Extended Mission Report) End-of-Mission Report
III (Flyby, Orbiter)	Mission Certification Planetary Protection Plan Planetary Protection Implementation Plan Pre-Launch Planetary Protection Report Post-Launch Planetary Protection Report (Planetary Protection Extended Mission Report) End-of-Mission Report
IV (Lander, Probe)	Mission Certification Planetary Protection Plan Planetary Protection Implementation Plan Pre-Launch Planetary Protection Report Post-Launch Planetary Protection Report (Planetary Protection Extended Mission Report) End-of-Mission Report
V "Unrestricted Earth return"	Documentation for outbound phase Certification of Unrestricted Earth return

## V "Restricted Earth return"

Documentation for outbound phase  
 Earth Safety Analysis Plan  
 Return Implementation Plan  
 Earth Pre-Return Report  
 Earth Pre-Entry Report  
 Sample Pre-Release Report  
 End-of-Mission Report

2.5.2 Planetary protection documents shall be submitted for review and approval, according to the schedule in Table 4, to be coordinated with KDP requirements given in NPR 7120.5. It is expected that the established dates be designated "control items" and reported in the normal monthly Project Management Reports.

2.5.2.1 The exact dates consistent with the schedule shall be determined in a manner agreeable to both PPO and Project Management and documented in the Planetary Protection Plan.

2.5.2.2 The Planetary Protection Implementation Plan and subsidiary documents (described in section 2.7.3.2) shall be made available to the PPO for discussion and review, to ensure that requirements are implemented appropriately, although formal approval is not required.

Table 4. Planetary Protection Documentation Schedule

<b><u>Report</u></b>	<b><u>Required Schedule</u></b>
Mission PP Categorization	Request for preliminary PP categorization to PPO during pre-Phase A/Phase 0. Request for formal PP categorization to PPO during Phase A.
<i>(if applicable) Certification for "Unrestricted Earth return"</i>	<i>No later than the end of Phase A.</i>
Planetary Protection Plan	Project-approved draft submitted to the PPO no later than end of Project's Conceptual Study Phase (Phase B). Approval and release before the Project's Preliminary Design Review (PDR).
PP Implementation Plan	Drafts made available to the PPO for discussion before the end of phase C. Approval by the project and release before the project's Critical Design Review (CDR).
<i>Earth Safety Analysis Plan</i>	<i>Approval and release prior to CDR.</i>
<i>Return Implementation Plan</i>	<i>Project approval prior to CDR.</i>
Subsidiary Plans	Project-approved draft submitted to the PPO no later than 3 months after completion of draft Planetary Protection Plan. Approval and release of all Subsidiary Plans before the Project's CDR.
Pre-Launch PP Report	Submitted to the PPO no later than 90 days prior to the scheduled launch. Includes Organics Inventory.
Post-Launch PP Report	Submitted to the PPO no later than 60 days after actual launch.
<i>Earth Pre-Return Report</i>	<i>Approval and release prior to the Earth Return Pre-Launch Review.</i>
<i>Earth Pre-Entry Report</i>	<i>Approval and release prior to the Earth Safety Analysis Review.</i>
<i>Sample Pre-Release Report (may be released in sections)</i>	<i>Approval and release prior to the Returned Sample Release Review and any release of sample material.</i>
Extended Mission PP Report	Submitted to the PPO no later than 60 days prior to scheduled end of the mission per the Planetary Protection Plan.

End-Of-Mission Report Submitted to the PPO no later than 60 days after the formally declared "End-of-Mission."

NOTE: Details of documentation content are presented in Section 2.7

2.5.3 Planetary protection implementation and compliance shall be reviewed as part of the formal documentation for the project. A summary of the required review schedule is presented in Table 5, and detailed requirements on review content are provided in section 2.8.

Table 5. Planetary Protection Review Schedule

<b><u>Review</u></b>	<b><u>Schedule</u></b>
Planetary Protection Plan	Review within 60 days of draft release.
Subsidiary Plans	Review within 60 days of draft release.
Pre-Ship PP Review	No earlier than 30 days prior to shipment.
Pre-Launch PP Review	Approximately 90 days prior to earliest scheduled launch date.
Flight Readiness Review	Project scheduled review.
Earth Return Pre-Launch Review	No earlier than 30 days or later than 7 days prior to earliest scheduled launch date to return from the sampled object.
Earth Safety Analysis Review	No earlier than 30 days or later than 7 days prior to commencement of Earth-commit trajectory.
Returned Sample Release Review	Following completion of the life detection and (may be done in separate segments) biohazard testing prescribed by the PP protocols and prior to release of sample material from containment.

2.5.4 In addition to the documents listed in Table 4 and detailed in section 2.7, any mission other than PP Category I that intends to enter an extended mission period (beyond the mission duration approved in the Planetary Protection Plan) shall submit a Planetary Protection Extended Mission Report, analogous to a Pre-Launch Report, that must be approved as part of the extended mission approval.

2.5.4.1 The status of planetary protection compliance during the flight mission and the health of the spacecraft shall be reviewed and summarized.

2.5.4.2 Demonstration of compliance with all applicable planetary protection requirements during the extended mission and the results of any necessary analysis for the extended mission shall be provided.

## 2.6 Deviations

2.6.1 Deviations from the requirements in this document may be permitted only after review and written approval by the PPO. Deviations from implementation procedures set forth in this NPR may be granted when an alternative implementation approach is demonstrated to meet planetary protection policy and objectives and is consistent with effective mission design and operations.

2.6.2 Deviations requested prior to the approval of the Planetary Protection Plan shall be proposed by describing alternative implementation approach(es) in distinct and separately identified part(s) of

the Planetary Protection Plan or other applicable subsidiary plan. Approval of the Planetary Protection Plan by the PPO will constitute written approval of proposed deviations so incorporated.

2.6.3 Deviations that are requested subsequent to the formal approval of the Planetary Protection Plan (or other applicable subsidiary plans) shall be obtained by submitting a request to the PPO in writing. Such requests should be transmitted via established program management channels. Requests must describe the need for a deviation and the justification to support the request, and include the impact of the requested change on the original analyses, as well as address possible changes in the PP category of the mission. The degree of compliance with all requirements must be addressed. The PPO will respond, in writing, to each request.

2.6.4 Requests for deviations after launch shall follow the process described in Section 2.6.3.

2.6.5 Changes involving major deviations within PP Category V shall, in addition to the above requirements, be approved, in writing, by the SMD AA.

2.6.6 Each deviation approved after completion of the Planetary Protection Plan shall be documented separately, for the record, in the Pre-Launch or End-of-Mission Report.

## **2.7 Detailed Documentation Requirements**

2.7.1 Missions certified as PP Category II or higher shall comply with additional constraints specific to the mission, as detailed in the PP categorization letter, in addition to those described in this document.

2.7.2 Documentation of compliance with implementation requirements is required based on PP category and shall include:

### **A. PP Category I missions:**

(1) Certification of mission as PP Category I relieves a project of all further planetary protection requirements.

### **B. PP Category II missions:**

(1) A Planetary Protection Plan outlining intended or potential impact targets.

(2) A brief Pre-Launch Planetary Protection Report detailing impact avoidance strategies.

(3) A brief Post-Launch Planetary Protection Report detailing actual trajectory and any updates previous documentation.

(4) End-of-Mission Report providing the final actual disposition of launched hardware and impact location.

### **C. PP Category III missions:**

(1) A Planetary Protection Plan that details the planned approach to compliance with planetary protection requirements, including subsidiary plans.

(2) A Planetary Protection Implementation Plan that details the project's implementation of the Planetary Protection Plan.

(3) A Pre-Launch Planetary Protection Report which documents that all requirements have been met (note that an inventory of bulk constituent organics, if the probability of impact is significant, must be included in the Pre-Launch Planetary Protection Report).

(4) A Post-Launch Planetary Protection Report that updates the Pre-Launch Planetary Protection Report.

(5) An End-of-Mission Report which provides a complete report of compliance, the final actual disposition of launched hardware, and, in the case of accidental impact, the probable location of impact and its region of uncertainty.

D. PP Category IV missions:

(1) A Planetary Protection Plan that details the planned approach to compliance with the implementation requirements (e.g., mission description, probability estimates, microbial burden estimates, contamination analysis plan, assay plan, microbial reduction plan).

(2) A Planetary Protection Implementation Plan that details the project's implementation of the Planetary Protection Plan.

(3) A Pre-Launch Planetary Protection Report that documents the degree to which all requirements have been met and that must include the values of the microbial burden at launch and the organics inventory.

(4) A Post-Launch Planetary Protection Report that updates the Pre-Launch Planetary Protection Report.

(5) An End-of-Mission Report that provides a complete report of compliance and the final disposition of all launched hardware.

(6) An inventory of bulk constituent organics that includes:

(a) Parts lists, material lists, and other program documentation containing data relevant to organic material identification that are prepared by a flight project to specify and control the materials that are included in a vehicle destined for planetary landing.

(b) The locations of landings and impact points (determined and defined as accurately as mission constraints permit) of major components of space vehicles on the planet surface,

(c) Estimates of the condition of each landed spacecraft to assist in calculating the spread of organic materials.

E. PP Category V missions certified as "Unrestricted Earth return" have no additional return phase requirements.

F. PP Category V missions certified as "Restricted Earth return" require:

(1) A Planetary Protection Plan, including outbound phase requirements, if any, and an Earth Safety Analysis Plan.

(2) A Planetary Protection Implementation Plan and Return Implementation Plan that details the project's implementation of the Planetary Protection Plan.

(3) A Pre-Launch Planetary Protection Report, including outbound phase requirements, if any, that must document the degree to which all Earth-return requirements to be attained prior to launch have been met.

(4) A Post-Launch Planetary Protection Report, including outbound phase requirements, if any, to update the Pre-Launch Planetary Protection Report with respect to Earth-return requirements.

(5) After sample collection, a report analogous to the outbound phase prelaunch reports: i.e., an



## Earth Pre-Launch Report.

(6) An Earth Pre-Entry Report demonstrating readiness to enter the Earth's atmosphere in compliance with planetary protection requirements.

(7) An End-of-Mission Report to address compliance with requirements for the protection of the Earth's biosphere and detailing the transfer of the samples to an appropriate containment facility.

(8) A Sample Pre-Release Report to provide verification of sample analysis procedures subsequent to the End-of-Mission and demonstrating that any planned sample release will not harm the Earth's biosphere.

2.7.3 Missions assigned PP Category II or higher shall provide the following planetary protection documentation, tailored appropriately to the mission PP category. Planning and documentation requirements for the return leg of PP Category V missions, including subsidiary plans, are described separately in section 2.7.4.

2.7.3.1 The Planetary Protection Plan is the primary planning document describing how a planetary flight project will meet its planetary protection requirements. It is a contractual agreement between the project and the NASA PPO.

a. The Planetary Protection Plan shall describe plans for compliance with applicable requirements and include, as a minimum, the items given in the following outline:

### A. General

(1) Introduction

(2) NASA Planetary Protection Constraints

a. Designation of Mission PP Category

b. Planetary Protection Specifications

### B. Planetary Protection Management and Organization

(1) Organization Description

(2) Responsibilities and Relationships

(3) System Interface Management

(4) Contractor Management

(5) Data Management

### C. Documentation

(1) Identification of References and Applicable Documents

### D. Facilities

(1) Identification and Description of Controlled Facilities

(2) Activities Performed

(3) Hardware Affected

### E. Schedules

(1) Identification of Milestones

(2) Preliminary Schedules

b. It is recognized that each project will prepare various other documents that may adequately cover some of the topics in the outline (e.g., the Project Plan may thoroughly cover the subject of Planetary Protection Management). In such instances, the Planetary Protection Plan may include only the major aspects of the topic and reference be made to other project documents that provide specificity. Such documents shall also be made available to the PPO.

c. The Planetary Protection Plan shall be prepared according to the schedule in section 2.5.



2.7.3.2 The following paragraphs modify specific PP Category II-V Mission Planning and Documentation requirements for the Planetary Protection Plan.

- a. For PP Category II missions, sections B (Planetary Protection Management and Organization) and D (Facilities) of the Planetary Protection Plan may be omitted. No subsidiary plans are required.
- b. For PP Category III missions, all of the items listed in sections 2.7.3.1.b shall be included, as well as subsidiary and implementation plans as appropriate. Probability of impact and planned contamination control procedures must also be directly addressed in the Planetary Protection Plan for PP Category III missions. If the mission involves an orbiter, the minimum planned periapsis altitude and planned final disposition of the hardware must be noted. If the orbiter chooses to meet the bioburden requirement, the Microbial Reduction Plan is required.
- c. For PP Category IV missions, all of the items listed in sections 2.7.3.1.b describing the Planetary Protection Plan, plus relevant subsidiary documents, shall be provided. The Contamination Analysis Plan and the Microbiological Assay Plan (subsidiary plans) are required. If any microbial reduction procedures are contemplated, the Microbial Reduction Plan is also required. These subsidiary plans are described in section 2.7.3.2.

2.7.3.3 For PP Category III and IV missions, including the outbound leg of PP Category V "Restricted Earth Return" missions, the following subsidiary implementation plans shall be prepared as appropriate for the particular PP category assigned:

- a. Contamination Analysis Plan (PP Category III and IV)
- b. Microbiological Assay Plan (PP Categories IV and III orbiters meeting the bioburden requirement)
- c. Microbial Reduction Plan (PP Categories IV and III orbiters meeting the bioburden requirement)

a. The Contamination Analysis Plan shall be the primary planning document covering the major analyses that are performed by the project and ultimately used to demonstrate to the PPO that the project is meeting the planetary protection requirements on microbial burden. This plan should include, but is not limited to, the items given in the following outline:

#### A. General

- (1) Introduction
- (2) Rationale and Assumptions

#### B. Potential Contaminating Sources

#### C. Microbial Burden Estimate Model

- (1) Contamination Sources Analysis
  - a. Analytical Techniques
  - b. Assumptions
  - c. Substantiation of Parameter Values
- (2) Allocation Model
  - a. Systems Allocations (Spacecraft, Launch Vehicle, etc.)
  - b. Subsystem and Lower Level Allocations

#### D. Analysis Documentation

b. The Microbiological Assay Plan shall identify the space vehicle hardware, facilities, and associated environments which are subject to microbiological assay; present the rationale, concepts, and detailed procedures pertaining to such assays; and describe the microbiological quality assurance procedures used to ensure validity of the assay results. The plan includes, but is not limited to, the items given in the following outline:

## A. General

- (1) Introduction
- (2) Rationale and Assumptions

## B. Assay Methods

- (1) Utilization of NASA HDBK 6022 , NASA Standard Procedures for the Microbiological Examination of Space Hardware. Alternative procedures, consistent with mission and life detection objectives, may be proposed by the Project for approval by the PPO.
- (2) Laboratory Assay Procedures
- (3) Sampling Procedures
- (4) Provision for Verification Assays
- (5) Quality Assurance Provisions

## C. Facilities

- (1) Controlled Facilities
  - a. Assay Laboratories
  - b. Hardware Areas
- (2) Uncontrolled Facilities
  - a. Monitoring
  - b. Environmental Estimates

## D. Space Hardware (Flight) Assay and Control

- (1) Identification
- (2) Hardware Exceptions
- (3) Contingency Planning

## E. Assay Data

- (1) Traceability
- (2) Analysis and Interpretation
- (3) Management and Handling

c. A Microbial Reduction Plan shall be submitted for planetary missions involving hardware elements that must have their microbial burden reduced to a specified or measured (assayed) level. The Microbial Reduction Plan includes, but is not limited to, the items in the following outline.

### A. General

- (1) Introduction
- (2) Rationale and Assumptions

### B. Spacecraft Hardware Subject to Microbial Reduction Processes

- (1) Identification
- (2) Exceptions/Deviations (see section 2.6)

### C. Process Analysis

- (1) Analytical Techniques
- (2) Assumptions
- (3) Process Parameters
- (4) Process Modification

### D. Process Verification and Control

- (1) Process Description and Boundaries
- (2) Process Qualification
- (3) Equipment and Facilities Qualification
- (4) Acceptance Criteria

## (5) Process Interruption and Modification

## (6) Quality Assurance Provisions

## E. Maintaining Reduced Microbial Level/Protection from Recontamination

## (1) Monitoring/Assaying

## (2) Using Microbial Barriers

## (3) Controlling Macro-organisms (Insects, Animals, etc.)

## (4) Contingency Planning

2.7.3.4 The Planetary Protection Implementation Plan (PP Categories III-V) is the reference document that shall describe, in detail, the processes, procedures, analyses, and facilities that are used to implement the Planetary Protection Plan and subsidiary plans.

2.7.3.5 The Pre-Launch Report is the main document used by a flight project to provide verification to the PPO that planetary protection requirements have been met (at the issue date of the document) and that the project will continue to satisfy planetary protection requirements throughout the mission. This document shall include, but not be limited to, the following information, which may be included as a part of the document or referenced from other documents. Reference documents may be submitted to the PPO as they are published.

a. A demonstration that all planetary protection constraints and requirements as noted in the Planetary Protection Plan will be met.

b. Identification of all approved planetary protection deviations (see section 2.6) from the Planetary Protection Plan.

c. Summaries of potentially significant violations of planetary protection requirements or procedures that could occur and thorough discussion of contingency planning associated with each potential event.

2.7.3.6 The following paragraphs modify specific PP Category II-IV Mission Planning and Documentation requirements.

a. For PP Category II missions, a report on any required contamination control measures shall be provided.

b. For PP Category III missions, the following information shall be provided:

(1) Calculations of microbial burden estimates.

(2) Report on required contamination control measures.

(3) Calculations of probability of impact.

(4) Organic materials inventory.

c. If the mission involves the use of hardware subject to microbial reduction processes, the verification that such processes have been properly applied shall be included. If the mission involves an orbiter as part of the launched hardware, the issue of orbital lifetime must also be addressed.

d. For PP Category IV missions, the requirements shall include the same information as for PP Category III, with information provided detailing the microbial reduction procedures employed and documentation supporting the results of the process.

2.7.3.7 After the launch of a planetary vehicle, PP Category II-V flight projects shall submit to the PPO a "Post-Launch Planetary Protection Report." This contains a brief summary document based on the "Pre-Launch Planetary Protection Report" but is updated to include the effects of launch and early postlaunch events. It demonstrates compliance with the overall planetary protection requirements through these early mission events.

2.7.3.8 At the formally declared "end-of-mission," PP Category II-V missions shall submit an End-of-Mission Report which documents the degree to which the mission has met the planetary protection requirements throughout the complete mission and reports the final disposition of all launched hardware.

a. This report shall document instances where planetary protection requirements were not fully met, including reasons for any deviations and projected consequences, to the degree they are known.

b. For some PP Category II and all III missions, an inventory of organic materials shall also be provided in the End-of-Mission Report for any spacecraft hardware, which unintentionally impacted or may impact protected solar system bodies within 50 years after launch.

2.7.4 PP Category V Earth-return missions certified for "Unrestricted Earth Return" have no formal implementation requirements on the return phase. Missions certified "Restricted Earth Return" shall complete the following plans:

2.7.4.1 The Earth Safety Analysis Plan is the primary planning document covering the Earth-return portion of the mission. Its purpose is to demonstrate to the PPO that the project is meeting its planetary protection requirements. This plan shall include, but is not limited to, the items given in the following outline:

A. General

- (1) Identification
- (2) Rationale and Assumptions

B. Potential Contaminating Sources

- (1) Sample Containment Approach
- (2) Decontamination Approach (if required)
- (3) Earth Entry Plan

C. Probability of Contamination Model

- (1) Mission Probability of Contamination Equation
- (2) Critical Parameters
- (3) Contamination Sources Analysis
  - a. Analytical Techniques
  - b. Assumptions
  - c. Substantiation of Parameter Values
- (4) Probability of Contamination Allocation Model
  - a. Level of Risk (provided to the Project by the PPO)
  - b. System Allocations (Return Capsule, Return Vehicle, etc.)

D. Analysis Documentation

2.7.4.2 The "Return Implementation Plan" is a document patterned after the Planetary Protection Implementation Plan used by a flight project. This document shall provide documentation to the PPO on how planetary protection requirements outlined in the Earth Safety Analysis Plan will be met and that the project can and will continue to satisfy them throughout the Earth-Return portion of the mission.

2.7.4.3 The "Earth Pre-Return Report" is a document patterned after the Planetary Protection Plan used by a flight project. This document shall provide verification to the PPO that planetary protection requirements outlined in the Earth Safety Analysis Plan have been met and that the project can and will continue to satisfy them throughout the Earth-Return portion of the mission.

2.7.4.4 After the launch of the Earth-return portion of the mission, the flight project shall submit to the PPO an "Earth Pre-Entry Report." This document updates the "Earth Pre-Return Report," to include the effects of launch and early postlaunch events, and demonstrates how the mission meets the overall planetary protection requirements.

2.7.4.5 In addition to the information provided and consistent with outbound phase requirements at the formally declared "end-of-mission," an End-of-Mission Report shall be submitted which documents the degree to which the mission has met its planetary protection requirements through landing and delivery of sample to containment in a Sample Receiving Facility. Special attention must be paid to the Earth's biosphere safety requirements of the mission.

2.7.4.6 Before an extraterrestrial sample is released to the general scientific community for investigation, a "Sample Pre-Release Report" shall be prepared certifying that, if released, the sample will not harm the Earth's biosphere. This report verifies that biohazard and life detection protocols have been executed and that samples are free of hazard to the Earth's biosphere and are, therefore, safe for release.

## 2.8 Detailed Review Requirements

2.8.1 For PP Categories III, IV, and V (Restricted Earth return), reviews shall be held to assure that planetary protection activities are proceeding properly. At a minimum, these include the reviews listed in Table 5. Additional formal and informal reviews may be held as warranted and as requested by the PPO or the project.

2.8.2 The PPO and/or designee shall be in attendance at these reviews. Generally, it is intended that formal planetary protection reviews be scheduled near the dates of project reviews or other technical reviews. Alternatively, the formal Planetary Protection reviews specified (see Table 6) may be incorporated as a segment of a broader project review.

Table 6. Planetary Protection Review Requirements

<u>Mission PP Category</u>	<u>Required Review</u>
I (Any)	None
II (Any)	Project PP Review (PPO Option)
III (Flyby, Orbiter)	<ol style="list-style-type: none"> <li>1. Project Planetary Protection Planning</li> <li>2. Pre-Ship Planetary Protection Review</li> <li>3. Pre-Launch Planetary Protection Review</li> <li>4. Flight Readiness Review</li> </ol>
IV (Lander, Probe)	<ol style="list-style-type: none"> <li>1. Project Planetary Protection Planning Review</li> <li>2. Pre-Ship Planetary Protection Review</li> <li>3. Pre-Launch Planetary Protection Review</li> <li>4. Flight Readiness Review</li> </ol>
V "Unrestricted Earth Return"	No further reviews beyond those for the outbound phase of the mission, as appropriate (see PP Categories I-IV)
V "Restricted Earth Return"	<ol style="list-style-type: none"> <li>1. Project Planetary Protection Planning Review</li> <li>2. Pre-Ship Planetary Protection Review</li> <li>2. Pre-Launch Planetary Protection Review</li> <li>3. Flight Readiness Review</li> <li>4. Earth Return Pre-Launch Review</li> <li>5. Earth Safety Analysis Review</li> <li>6. Returned Sample Release Review</li> </ol>



2.8.3 The content and scheduling of planetary protection reviews shall be developed in discussions between the PPO and various organizational elements of the project. Planetary protection reviews may be held as splinter meetings of other required project reviews. Action items which may result from these reviews should be tracked and closed out by the same quality control processes/procedures the project uses for resolving action items resulting from other formal technical reviews.

2.8.3.1 A Planetary Protection Planning Review shall be held, at the request of either the PPO or the project's authorized representative, at the start of the project's planning phase and no later than when the draft version of the project's Planetary Protection Plan is near completion. The purpose of conducting this review at this time is to enable the PPO to review the implementation strategies considered by the project and suggest such changes to the project's planetary protection planning as are necessary for the formal version of the Planetary Protection Plan to be approved without major change or delay. The PPO may require that all action items resulting from these reviews be closed out before formal approval of the Planetary Protection Plan. Approval of the mission's Planetary Protection Plan constitutes formal PP categorization of the mission for planetary protection purposes.

2.8.3.2 The Pre-Ship Planetary Protection Review shall be conducted, prior to the shipment of the spacecraft to the launching site, for all missions assigned to PP Categories III, IV, and V. The PPO conducts this review to ascertain the project's compliance with PP requirements and the adequacy of planned PP-related activities and staffing at the launch site.

2.8.3.3 The Pre-Launch Planetary Protection Review shall be conducted, approximately 90 days prior to launch, for all missions assigned to PP Categories III, IV, and V. The PPO conducts this review to ascertain whether a project has, to that date, met its planetary protection requirements. As a part of this review, the PPO will also examine, in detail, the planetary protection activities accomplished prior to this review, as well as those remaining prior to launch. The "Pre-Launch Planetary Protection Report" (see section 2.7.3.5) forms the framework for this review.

2.8.3.4 The project's formal Flight Readiness Review, for all missions assigned to PP Categories III, IV, and V, shall include planetary protection as a topic. The PPO participates in this review to ensure that planetary protection requirements continue to be met. Various events detrimental to planetary protection could occur subsequent to the Pre-Launch Planetary Protection Review and prior to actual launch of the vehicle. Significant planetary protection events, problems, changes, open action items, etc., that have occurred since the Pre-Launch Planetary Protection Review must be addressed.

2.8.3.5 The Earth Return Pre-Launch Review shall be conducted, prior to initiation of the Earth return portion by launch from the sampled object, for all missions assigned to PP Category V "Restricted Earth Return." The PPO conducts this review to ascertain that a project has, to that date, met its planetary protection requirements and makes a recommendation to the SMD AA regarding readiness for Earth Return. As a part of this review, the PPO will also examine, in detail, the planetary protection activities accomplished prior to this review, as well as those remaining prior to initiation of Earth return. The formally released edition of the "Earth Pre-Return Report" (see section 2.7.4.3) forms the framework for this review.

2.8.3.6 The Earth Safety Analysis Review shall be conducted prior to committing a spacecraft to the Earth return portion of its mission for all missions assigned to PP Category V, "Restricted Earth Return." The PPO conducts this review to determine whether all planetary protection requirements have been met and will continue to be met throughout the duration of the mission. The formally released document "Earth Safety Analysis Plan" (see section 2.7.4.1), as updated by the Earth Pre-Entry Report (see section 2.7.4.4), forms the framework for this review. This review may be

attended by the SMD AA and members of an Interagency Committee, which will be overseeing activities related to the handling and testing of the returned sample in the Receiving Facility.

2.8.3.7 One or more Returned Sample Release Review(s) shall be conducted prior to release of any extraterrestrial sample that was returned by a mission assigned to PP Category V "Restricted Earth Return." The PPO conducts this review to ascertain that all planetary protection requirements, including the execution of prescribed life detection and biohazard protocols have been met. The formally released document "Sample Pre-Release Report"(see section 2.7.4.6), or an appropriate section of that report, forms the framework for the review. This review must be attended by members of the Interagency Committee and by the SMD AA, whose approval must be obtained before release of the samples.

## **2.9 Coordination with Orbital Debris Requirements**

2.9.1 Planning for the Earth Return portion of PP Category V missions shall be coordinated with relevant requirements for limiting orbital debris, particularly NPR 8715.6.

2.9.2 Planetary protection documentation for end-of-mission scenarios that involve hardware disposition in the vicinity of Earth or the Earth's Moon may be coordinated with activities and documentation required for purposes of orbital debris mitigation. For example, projects may request the NASA Orbital Debris Program Office to provide analysis and review support for Planetary Protection reentries, including survivability modeling, reentry heating, and interface with USAF tracking resources.



# Chapter 3. Planetary Protection Constraints

## 3.1 General

3.1.1 Planetary protection constraints shall be imposed according to the contents of this document, as may be applicable to each mission.

3.1.2 Specific deviations from individual constraints may be requested by a flight project in accordance with the provisions of section 2.6, Deviations.

## 3.2 Specification of Parameters

3.2.1 In order for a flight project to plan for compliance with planetary protection requirements, appropriate mission specific parameters and specifications (such as the microbial burden requirement for a mission type to a given target planet) shall be obtained from the PPO during Phase A.

3.2.1.1 Each major parameter and specification shall be defined and its value specified on a "Parameter Specification Sheet" which is valid when dated and signed by the PPO. Flight projects may use applicable values specified therein without further authorization. Approved planetary protection parameter specifications are included in Appendix D.

3.2.1.2 Deviations from specified values shall be handled per section 2.6.

3.2.2 The values adopted by a project for undesignated parameters and specifications shall be subject to the approval of the PPO. These project-developed parameters and specifications must be included in the "Planetary Protection Plan" with later changes reflected in the "Pre-Launch Planetary Protection Report." Approval of these documents will constitute approval of the parameters and specifications contained therein. Alternatively, a project manager may request that the PPO issue appropriate Parameter Specification Sheets based on submitted new information and data.

3.2.3 In addition to the primary purpose of designating parameters and specifications used in mission planning, Parameter Specification Sheets also may be used for other purposes, such as defining contamination-related process parameters (e.g., minimum temperature for microbial reduction processes, etc.).

## 3.3 Microbiology Related Determinations

3.3.1 Missions with bioburden constraints shall monitor and document bioburden carried on spacecraft hardware using approved methods.

a. Approved protocols for the microbiological assay of spacecraft hardware and their associated environments are provided in the current version of NASA HDBK 6022, "NASA Standard Procedures for the Microbiological Examination of Space Hardware," as supplemented by the project's "Microbiological Assay Plan."

b. Alternative assay procedures consistent with mission and life detection objectives may be proposed to the PPO for review and approval prior to use.

3.3.2 In addition to those microbiological assays which a flight project organization or its contractors

may wish to conduct, various verification assays (see section 2.4) shall be conducted for the PPO by an organization designated by the PPO. Collection of samples for verification assays from flight hardware may be delegated to involved flight project and contractor organizations, under supervision.

3.3.2.1 Microbial samples taken from spacecraft hardware, the assembly facility environment, etc. shall be furnished to the PPO by the flight project (or contractors) in accordance with the quantity and locations identified in the Microbiological Assay Plan. Collection of microbiological samples may, at the option of the PPO, be subject to observation by the PPO or his/her designated representative. Microbiological samples will be processed by the organization designated by the PPO to obtain pertinent data (e.g., microorganism types and numbers).

3.3.3 In the event of significant discrepancies between project assays and verification assays due to possible laboratory contamination, the PPO shall take appropriate action to review the suspect data and resolve the discrepancies. An Assay Review Board may be formed to review the suspect data and their causes.

## **3.4 Microbial Reduction**

3.4.1 Microbial reduction for planetary spacecraft (including planetary entry probes and planetary landing capsules) shall be accomplished by an approved process.

a. Alternate methods of microbial reduction may be proposed, such as by chemical or radiation techniques or various combinations of these techniques with heat.

3.4.1.1 Approval of alternative methods shall be based on a rigorous examination of supplied data which must demonstrate conclusively the biological effectiveness and reproducibility of the alternate method for the specific application under consideration.

3.4.1.2 It may be desirable to subject either all or certain elements of the spacecraft hardware to a microbial reduction process prior to their assembly. Approval from the PPO shall be obtained for use of methods other than those approved for an entire spacecraft, according to the following criteria:

a. A statement shall be made in the Planetary Protection Plan that unique microbial reduction techniques or processes different from those applied to hardware during the microbial reduction of the entire spacecraft are proposed for use.

b. Each unique microbial reduction technique or process cycle shall be described in a process specification in the Microbial Reduction Plan that provides documentation regarding the biological qualification and quality assurance requirements applicable to the process.

c. The microbial reduction process specification to be used on an individual item of hardware shall be cited in its detailed engineering specification, as an applicable document.

d. The unique microbial reduction techniques or process cycles employed shall not degrade the ability of the spacecraft to withstand the standard "dry heat" or other approved process cycles to be applied to the entire spacecraft.

3.4.2 Following the successful application of a microbial reduction process, appropriate measures shall be taken to prevent recontamination.

3.4.2.1 Preplanned operations involving the use of microbial barriers after microbial reduction processes have been conducted may be proposed as part of the Planetary Protection Plan or

## Subsidiary Plans.

3.4.2.2 If the use of microbial barriers is proposed, the appropriate plan shall describe the operation and qualification of both the hardware and techniques to be used.

3.4.2.3 Specific constraints applicable to the design and operation of spacecraft microbial barriers are given in the appropriate Specification Sheets (Appendix D).

3.4.3 The specification of basic microbial reduction parameters shall be made in one or more of the Microbial Reduction Plan, Parameter Specification Sheets, or contractor-prepared documents submitted for approval. Approval of these documents by the PPO constitutes approval of the parameters specified therein.

3.4.4 In no case shall basic parameters of microbial reduction processes (e.g., temperature, radiation type, etc.) be made binding in contractual instruments or governing project documents without documented approval of these parameters by the PPO.

3.4.5 Microbial Reduction Calculations shall be performed according to the following procedures:

3.4.5.1 Calculations involving the death rates of populations of microorganisms subjected to sterilizing conditions shall be based on a death rate model (kill curve) approved by the PPO.

3.4.5.2 Parameter values, other than those specified in applicable Parameter Specification Sheet, that are used in calculating microbial reduction process cycles shall be supported by data from reproducible laboratory tests or by suitable technical references.

3.4.5.3 A calculation of the microbial reduction produced by a given process shall demonstrate that the predicted number of microorganisms surviving the process does not exceed the acceptable value given in the "Pre-Launch Planetary Protection Report."

3.4.5.4 For microbial reduction process cycles that use transient lethality effects, the value of parameter used to begin lethality calculations shall be as stated in the appropriate Parameter Specification Sheet or approved documentation.

3.4.5.5 The minimum steady-state value of the parameter used for a microbial reduction treatment cycle shall not be less than that specified in either the approved Microbial Reduction Plan or in a Parameter Specification Sheet.

3.4.6 Verification that a spacecraft has undergone the required degree of microbial reduction shall be provided to the PPO.

3.4.6.1 Microbiological assay of the interior of the spacecraft subsequent to the application of the microbial reduction process may be avoided by providing documentation of the following constraints:

- a. Approved microbial reduction processes were used.
- b. The microbial burden of the spacecraft prior to the application of the microbial reduction process has been measured or estimated (by a means acceptable to the PPO) to be within limits that will allow the planned microbial reduction process to be adequate.
- c. The specified microbial reduction process parameters, such as time, atmospheric composition (including water vapor), and temperature, have been properly imposed on the spacecraft hardware.

## **3.5 Launch and Post-Launch Operations (PP Categories III-V)**

3.5.1 As a part of launch operations, the PPO shall verify that planetary protection requirements have been met and that the mission may be launched.

3.5.1.1 Prior to final launch approval, the PPO shall provide, to the SMD AA, a letter certifying that the project has complied with planetary protection requirements.

3.5.1.2 To assure that planetary protection requirements are met throughout launch operations and until the spacecraft leaves the atmosphere, the PPO (or designated representative) shall be present at the launch site during launch operations.

3.5.1.3 To provide a basis for verification of planetary protection compliance, the project shall make available, to the PPO, pertinent information and documentation generated since the Pre-Launch Planetary Protection Review and the Launch Readiness Review, as well as real-time information relevant to planetary protection aspects of launch operations.

3.5.2 Changes from the original mission plan that become necessary as a result of postlaunch anomalies shall be approved by the PPO before implementation if such changes potentially could affect compliance with planetary protection requirements (also see section 2.6)

# Chapter 4. Management

## 4.1 Project Plan

4.1.1 The management relationships established for the conduct of a specific planetary flight project shall be as described in the applicable Project Plan.

4.1.2 Each planetary flight mission Project Plan shall be reviewed by the PPO to ensure that management relationships permit the SMD AA to fulfill his/her responsibilities as identified in NPD 8020.7.

## 4.2 Delegated Responsibilities of the Planetary Protection Officer

4.2.1 The responsibilities delegated by the SMD AA to the PPO are identified in NPD 8020.7. In discharging those responsibilities, the PPO shall:

- a. Represent the SMD AA in external technical activities in the area of planetary protection. This includes consultation with other U.S. Government agencies, with representatives of other nations and space agencies, and coordination with international bodies such as the COSPAR.
- b. Maintain liaison with the secretariat and members of the SSB of the NRC and the NASA Advisory Council to formally advise them of NASA planetary protection policy and major actions and to seek their advice and counsel.
- c. Establish planetary protection requirements applicable to each planetary flight program/project; coordinate and interpret these requirements with appropriate representatives of the planetary flight program and project offices; establish methods to verify that planetary protection requirements have been met.
- d. Provide support to planetary flight program/project offices in the following areas, as may be agreed to by the appropriate flight program and project managers and the PPO:
  - (1) Preparing guidelines, reviewing procedures, interpreting planetary protection documents when necessary, clarifying requirements, and other such information that may be useful to the flight program/project in meeting planetary protection requirements.
  - (2) Reviewing, concurring, or approving procedures, standards, specifications, and other documents used to control factors impacting planetary protection.
  - (3) Providing for the performance of biological assays to supplement those performed by a flight program/project, if applicable.
  - (4) Coordinating closely with flight program/project managers and providing recommendations and guidance as required.
- e. Provide oversight of flight program/project activities as required to ascertain the extent of flight program/project adherence to established planetary protection requirements. This may involve the following:
  - (1) Performing verification assays of environments, facilities, and flight hardware independent of assays conducted by flight programs/projects.

(2) Monitoring activities and reviewing records and data generated by a flight program/project which are used to verify compliance with planetary protection requirements.

(3) Observing significant development and qualification tests and flight program/project operations to verify conformance with approved procedures and plans.

f. Establish and support research and technology development so that state-of-the-art methodologies are incorporated into the implementation of planetary protection policy.

4.2.2 In addition to responsibilities delegated from NPD 8020.7, in the context of robotic missions the PPO shall consult and coordinate with the Office of the Chief Health and Medical Officer regarding health and medical issues related to planetary protection requirements (e.g. "backward contamination") to ensure coordination with existing NASA health and medical policy.

# Chapter 5 Detailed Planetary Protection Requirements

## 5.1 Numerical Implementation Limits for Forward Contamination Calculations not Otherwise Specified

5.1.1 To the degree that numerical limits are required to support the overall policy objectives of this document, and except where numerical requirements are otherwise specified, the limit to be used is that the probability that a planetary body will be contaminated during the period of biological exploration shall be no more than  $1 \times 10^{-3}$ . No specific format for probability of contamination calculations is specified.

5.1.2 The period of biological exploration shall extend at least 50 years after a PP Category III or IV mission arrives at its protected target and no longer than the time point after which no organisms remain viable on the spacecraft.

5.1.3 For all launch vehicle elements leaving Earth's orbit, the probability of impacting Mars shall be less than  $1 \times 10^{-4}$  for a period of 50 years. The probability of impact assessment should be provided in the Planetary Protection Plan.

5.1.4 For all spacecraft crossing Mars orbit en route to other targets, the probability of impacting Mars shall be less than  $1 \times 10^{-2}$  for a period of 50 years. The probability of impact assessment should be provided in the Planetary Protection Plan.

5.1.5 In the context of missions to icy satellites, "contamination" is defined as the introduction of a single viable terrestrial microorganism into a liquid-water environment.

## 5.2 PP Category-Specific Listing of Target Body/Mission Types (advisory only)

5.2.1 PP Category I (Flyby, Orbiter, Lander): Undifferentiated, metamorphosed asteroids; Io; others TBD

5.2.2 PP Category II (Flyby, Orbiter, Lander): Venus; Moon (with organic inventory); Comets; Asteroids (other than those covered in 5.2.1); Jupiter; Jovian Satellites except Io, Ganymede\* (see 5.2.2.1 for explanation of the asterisk), and Europa; Saturn; Saturnian Satellites other than Titan\* and Enceladus; Uranus; Uranian Satellites; Neptune; Neptunian Satellites other than Triton\*; Pluto\*/Charon\*; Kuiper-Belt Objects

5.2.2.1 The mission-specific assignment of objects designated with an asterisk (\*) to Category II shall be supported by an analysis of the "remote" potential for contamination of the liquid-water environments that may exist beneath their surfaces (a probability of  $< 1 \times 10^{-4}$  of introducing a single viable terrestrial microorganism), addressing both the existence of such environments and the prospects of accessing them.

5.2.3 PP Category III (Flyby, Orbiter): Mars; Europa; Enceladus; others TBD.

5.2.4 PP Category IV (Lander): Mars; Europa; Enceladus; others TBD



5.2.5 PP Category V (Any Earth-return): "Restricted Earth return": Mars; Europa; Enceladus; others TBD; "Unrestricted Earth return": Venus, Moon; others TBD.

## 5.3 PP Category-specific Requirements for Mars

*Note: All bioburden constraints are defined with respect to the number of aerobic microorganisms that survive a heat shock of 353 Kelvin (80C) for 15 minutes and are cultured on Trypticase Soy Agar at 305 Kelvin (32C) for 72 hours (hereinafter "spores").*

5.3.1 PP Category III and IV missions to Mars shall comply with all applicable requirements, including appropriate margin.

5.3.1.1 A probability of impact assessment shall be provided for all launch vehicle elements leaving Earth's orbit, covering the first fifty years after launch.

5.3.1.2 Cruise stages, flyby, and orbiter spacecraft shall avoid Mars impact at a probability no less than 0.99 for 20 years after launch and a probability no less than 0.95 for the period 20-50 years after launch.

5.3.1.3 Mars orbiters shall include the probability of impact on approach in their calculations, unless numerical bioburden requirements are met at launch.

5.3.1.4 Spacecraft that do not meet impact avoidance constraints shall limit their total (surface, mated, and encapsulated) bioburden level to  $5 \times 10^5$  spores.

5.3.2 PP Category IV for Mars is subdivided into IVa, IVb, and IVc. Missions shall comply with requirements appropriate to the subcategory they have been assigned. Requirements for missions carrying life detection instruments that access special regions will include a combination of those listed under IVb and IVc, as determined on a mission-by-mission basis.

5.3.2.1 PP Category IVa. Lander systems not carrying instruments for the investigations of extant Martian life shall:

- a. Be restricted to a surface biological burden level of  $3 \times 10^5$  spores in total and an average of 300 spores per square meter of exposed external and internal spacecraft surfaces.
- b. Provide an assessment of Entry, Descent, and Landing (EDL) expected performance against environmental and other design cases, identifying included and excluded factors, and, to the extent available, quantitative assessments of confidence levels.

5.3.2.2 PP Category IVb. Lander systems designed to investigate extant Martian life shall comply with all of the requirements of PP Category IVa and also with one of the following requirements:

### **EITHER**

- a. The entire landed system is restricted to a surface biological burden level of 30 spores (see 5.3.2.4) or to levels of biological burden reduction driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent, and protected from recontamination.

### **OR**

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

5.3.2.3 PP Category IVc. Missions investigating Martian special regions (see section 5.3.2.4), even if they do not include life detection experiments, shall comply with all of the requirements of PP Category IVa and also the following:

- a. For missions landing within a special region, the entire landed system shall be restricted to a surface biological burden level of 30 spores (see 5.3.2.4).
- b. For missions accessing a special region though horizontal or vertical mobility, one of the following requirements shall be imposed:

**EITHER**

(1) The entire landed system is restricted to a surface biological burden level of 30 spores (see 5.3.2.4);

**OR**

(2) The subsystems which directly contact the special region are sterilized to these levels, and a method of preventing their recontamination prior to accessing the special region is provided.

c. If the probability of a non-nominal landing in a special region (including EDL and spacecraft-induced special regions) is greater than 0.01, then the entire landed system shall be sterilized to the following levels: a surface biological burden level of 30 spores (see 5.3.2.4) and a total (surface, mated, and encapsulated) bioburden level of  $1.5 \times 10^4$  spores (see 5.3.2.4).

5.3.2.4 The 30 spore figure takes into account the occurrence of hardy organisms with respect to the sterilization modality. This specification assumes attainment of PP Category IVa surface cleanliness, followed by at least a four order-of-magnitude reduction in viable organisms. Verification of bioburden level is based on presterilization bioburden assessment and knowledge of reduction factor for the sterilization modality.

5.3.2.5 A Special Region shall be defined as a region within which terrestrial organisms are likely to replicate. Any region which is interpreted to have a high potential for the existence of extant Martian life forms is also defined as a Special Region.

a. Given current understanding of terrestrial organisms, Special Regions are defined as areas or volumes within which sufficient water activity AND sufficiently warm temperatures to permit replication of Earth organisms may exist. The physical parameters delineating applicable water activity and temperature thresholds are given below:

- (1) Lower limit for water activity: 0.5 aw; Upper limit: 1.0 aw
- (2) Lower limit for temperature: -25C; No Upper limit defined
- (3) Timescale over which limits apply: 500 years

b. Observed features for which there is a significant (but still unknown) probability of association with liquid water and which should be classified as Special Regions:

- (1) Gullies and bright streaks associated with gullies
- (2) Pasted-on terrains
- (3) Subsurface below 5 meters
- (4) Others, to be determined, including dark streaks, possible geothermal sites, fresh craters with hydrothermal activity, modern outflow channels, or sites of recent seismic activity.

c. Spacecraft-induced Special Regions are to be evaluated, consistent with these limits and features, on a case-by-case basis.

d. In the absence of specific information, no Special Regions are currently identified on the basis of possible Martian life forms. If and when information becomes available on this subject, Special Regions shall be further defined on that basis.

5.3.3 PP Category V. The Earth return portion of a Mars Sample Return mission is classified as "Restricted Earth return," with all outbound portions required to meet associated requirements. Guidelines for sample return missions are as follows:

5.3.3.1 Samples returned from Mars by spacecraft shall be contained and treated as though potentially hazardous until demonstrated otherwise.

5.3.3.2 Unless specifically exempted, the outbound leg of the mission shall meet PP 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. 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.

5.3.3.3 Unless the sample to be returned is subjected to an accepted, approved, sterilization process, the sample container must be sealed after sample acquisition, and a redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required.

5.3.3.4 For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

5.3.3.5 The mission and the spacecraft design shall provide a method to "break the chain of contact" with Mars. No uncontained hardware that contacted Mars, directly or indirectly, may be returned to Earth unless sterilized. Isolation of such hardware from the Mars environment must be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.

5.3.3.6 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 reentry.

5.3.3.7 For unsterilized samples returned to Earth, 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.

5.3.3.8 Because of the lengthy time needed for the complex development of a sample-receiving facility (SRF) and its associated biohazard-test protocol, instrumentation, and operations, planning for an SRF shall be included in the earliest phases of the Mars sample return mission.

5.3.3.9 A sample-receiving facility shall be completed and fully operational prior to the return of samples to Earth, on a timescale that allows ample time for integrated testing of the facility, the instrumentation, and the NASA life detection and biohazard test protocol, well in advance of receiving returned Martian materials.

5.3.3.10 A sample-receiving facility shall employ appropriately certified personnel and instrumentation to validate and perform the battery of tests described in the NASA life detection and biohazard test protocol that will be used to determine whether and when unsterilized materials returned from Mars may be approved for controlled distribution or full release from containment.

5.3.3.11 An independent science and technical advisory committee shall be constituted with oversight responsibilities for materials returned by a Mars sample return mission.

## 5.4 PP Category II\*/III/IV Requirements for Icy Satellites

5.4.1 PP Category II\*, III and IV. (For an explanation of the II\* designation, see section 5.2.2.1.) Requirements for flybys, orbiters, and landers to icy satellites, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of an ocean or other liquid water body to less than  $1 \times 10^{-4}$  per mission. The calculation of this probability shall include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

- A. Bioburden at launch
- B. Cruise survival for contaminating organisms
- C. Organism survival in the radiation environment adjacent to the target
- D. Probability of encountering/landing on the target, including spacecraft reliability
- E. Probability of surviving landing/impact on the target
- F. Mechanisms and timescales of transport to the subsurface
- G. Organism survival and proliferation before, during, and after subsurface transfer

5.4.1.1 Preliminary calculations of the probability of contamination suggest that bioburden reduction will likely be necessary for PP Category III orbiters, as well as for PP Category IV 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.

5.4.2 PP Category V for Europa and Enceladus. The Earth return mission is classified "Restricted Earth return."

5.4.2.1 Unless specifically exempted, 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.

a. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later missions.

5.4.2.2 Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition, and a redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required.

5.4.2.3 For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

5.4.2.4 The mission and the spacecraft design shall provide a method to "break the chain of contact" with the target.

5.4.2.5 No uncontained hardware that contacted the target, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the target environment must be provided during sample container loading into the containment system, launch from the target, and any in-flight transfer operations required by the mission.

5.4.2.6 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 target for return to Earth; and 3) prior to commitment to Earth reentry.

5.4.2.7 For unsterilized samples returned to Earth, 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.

## 5.5 Requirements for Small Solar System Bodies

5.5.1 PP 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 are likely to be assigned to PP Categories I or II. Further elaboration of this requirement is anticipated.

5.5.2 PP Category V. Determination as to whether a mission is classified "Restricted Earth return" or "Unrestricted Earth return" shall reflect the best multidisciplinary scientific advice and review, 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)*.

5.5.2.1 Specifically, such a determination shall consider six questions for each body intended to be sampled. Containment procedures are necessary ("Restricted Earth return") if an answer of "yes" or "uncertain" is returned to each of the six questions, below. A "no" answer to any one of these questions would indicate that containment of returned samples from the target body is not necessary for planetary protection purposes ("Unrestricted Earth return"):

Does scientific evidence indicate that:

1. There was ever liquid water in or on the target body?
2. Metabolically useful energy sources are or were ever present?
3. Sufficient organic matter (or CO<sub>2</sub> or carbonates and an appropriate source of reducing equivalents to support life) was ever in or on the target body?
4. Subsequent to the disappearance of liquid water, the target body has remained below the temperature of presumptive biological sterilization (e.g.,
5. The target body has not been exposed to sufficient radiation for presumptive biological sterilization (e.g., by analogy to the tolerances of terrestrial organisms)?
6. There is no natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

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

5.5.3.1 Unless specifically exempted, 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.

- a. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later missions to that body.



5.5.3.2 Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container shall be sealed after sample acquisition, and a redundant, fail-safe containment with a method for verification of its operation before Earth-return be required.

5.5.3.3 For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

5.5.3.4 The mission and the spacecraft design shall provide a method to "break the chain of contact" with the small body. No uncontained hardware that contacted the body, directly or indirectly, may be returned to Earth. Isolation of such hardware from the body's environment must be provided during sample container loading into the containment system, launch from the body, and any in-flight transfer operations required by the mission.

5.5.3.5 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 reentry.

5.5.3.6 For unsterilized samples returned to Earth, 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.

## **5.6 Additional Implementation Guidelines for PP Category V Missions**

5.6.1 If, during the course of a PP Category V mission there is an increase in the level of concern, due to a change in the circumstances that led to its classification or a mission failure, then the sample to be returned shall be abandoned.

5.6.1.1 If the sample is already collected, the spacecraft carrying it shall not be allowed to return to the Earth or the Moon.

5.6.2 Examples of such changes include:

a. 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.

b. The sample containment system of a mission classified as "Restricted Earth return" is thought to be compromised, and sample sterilization is impossible.

c. Others TBD.



# Appendix A. Definitions

A.1 Assay (also referred to as "bioassay"). Any activities related to gathering of microbial data through the use of appropriate sampling techniques (swabs, wipes or other approved methods) to obtain microbial samples in order to estimate the number or types of microorganisms associated with an item of interest.

A.2 Constraints. Bounding conditions governing aspects of the implementation of planetary protection requirements.

A.3 Encapsulated (or Embedded) Bioburden. Microbial burden buried inside nonmetallic spacecraft material.

A.4 Exposed Surfaces. Those surfaces whose microbial burden will likely reach a planetary environment following the nominal landing of a spacecraft. For dry heat considerations, a surface that is free for gas exchange.

A.5 Mated Surfaces. Surfaces joined by fasteners rather than by adhesive.

A.6 Microbial Barrier or Biobarrier. A means to protect a spacecraft or associated component(s) against microbial recontamination following the application of microbial reduction procedures.

A.7 Microbial Bioburden (also referred to as "Biological Burden" or "Bioburden"). The level of microbial contamination (total number of microbes, spores and nonheat shocked, or microbial density) in or on an item of interest.

A.8 Microbial Monitoring. The collection, analysis, and associated activities that are performed to verify the biological condition of an item of interest.

A.9 Microbial Reduction (also referred to as "Bioburden Reduction"). Any activities designed to remove or destroy microbes that are performed in order to reduce microbial burden levels on or in an item of interest.

A.10 Organics Archive. A stored collection of bulk organic constituents (materials) of all launched hardware.

A.11 Organics Inventory. An itemized list of bulk organic materials used in launched hardware.

A.12 Planet (or "Target Body"). As used in this document, the term includes major planets, planet satellites, and other solar system objects that may be of scientific interest.

A.13 Planetary Protection. The protection of a planet from terrestrial contaminants and the protection of the Earth's biosphere from potentially harmful extraterrestrial material.

A.14 Spore (or endospore). A structure formed by the actively growing (vegetative) stage of some bacteria that is able to remain viable under extremely harsh environmental (heat, dryness, radiation) conditions and, when the environment improves, once again actively grow and proliferate. As used in this document and in the appropriate requirements and specifications, spore refers to a heat shock surviving microbe culturable in the NASA standard assay.

A.15 Sterilization. As used in this document, the process of actively reducing the microbial burden on flight hardware so that the hardware is nearly free (consistent with the appropriate specifications) of all living microorganisms.

A.16 Terminal Sterilization. A final sterilization process applied to the entire spacecraft system.

A.17 Total Bioburden. Total of exposed, mated, and encapsulated microbial burden.

A.18 Verification Assay. A microbiological assay performed as requested and directed by the PPO to verify compliance with planetary protection requirements.

# Appendix B. Acronyms

AU	astronomical unit
aw	water activity
C	Celsius
CDR	Critical Design Review
COSPAR	Committee on Space Research
EDL	Entry, Descent, and Landing
HDBK	Handbook
KDP	Key Decision Point
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NRC	National Research Council
PDR	Preliminary Design Review
PP	Planetary Protection
PPO	Planetary Protection Officer or designee
PQAP	Planetary Quarantine Advisory Panel
SMD AA	Associate Administrator for the Science Mission Directorate
SRF	sample-receiving facility
SSB	Space Studies Board
TBD	to be determined
U.S.C.	United States Code

# Appendix C. Procedural Guidelines for Flight Projects: Communications with the Planetary Protection Officer

## C.1 Introduction

C.1.1 NASA's formal Planetary Protection Policy and requirements documents, NPD 8020.7 and NPR 8020.12, detail overall planetary protection policy and requirements; assign and describe responsibilities; and provide specifications for key parameters involved in the implementation of requirements. These guidelines supplement those documents by describing a model process, consistent with NPD 8020.7 and NPR 8020.12, for the flow of communications between flight projects and the NASA Planetary Protection Officer and her/his staff and consultants at NASA Headquarters (hereinafter, "the PPO"). The purpose of these guidelines is to provide flight projects useful information to facilitate their implementation of planetary protection requirements, enable effective and timely communications, and contribute to the success of their missions.

## C.2 Preproject Phase

C.2.1 Projects can benefit from communication with the PPO at NASA Headquarters even during preproject activities. Although not formally a part of planetary protection requirements, it is suggested that a project request a preliminary planetary protection categorization of the mission during the early stages of mission planning. A preliminary planetary protection categorization may be required by specific language in an Announcement of Opportunity. Prior to submitting a written request, the project is encouraged to communicate informally with the PPO.

## C.3 Phase A-B

C.3.1 During the early stages of the project, and no later than the end of Phase A, the project manager (may be the Principal Investigator on competitive missions) should request from the PPO, in writing, the formal planetary protection categorization of the mission. Again, informal communication with the PPO is encouraged prior to submittal of this request letter to ensure that the request is comprehensive and phrased appropriately.

C.3.2 After receipt of a PP Categorization Letter from the PPO, the Project should submit a Planetary Protection Plan, unless the project received a PP Category I categorization, which exempts it from any subsequent requirements. A Project-approved draft of the Planetary Protection Plan is due no later than the end of Phase B (conceptual study phase), with the formal release of the plan due no later than the Project's Preliminary Design Review (PDR). For PP Category II missions, as well as PP Category V-unrestricted Earth return, the Planetary Protection Plan is a fairly straightforward undertaking and may require only limited interaction with the PPO. To address any questions or issues that may arise, direct communication with the PPO is encouraged.

C.3.3 For missions assigned PP Categories III, IV, and V-restricted Earth return, preparation of the Project's Planetary Protection Plan is significantly more involved and complex. Development of such a Planetary Protection Plan requires frequent interaction with the PPO, the extent of which will depend on the PP category and degree of mission complexity. During the evaluation of alternative

implementation strategies, communication with the PPO is necessary to ensure that the strategies are consistent with NASA's Planetary Protection Policy and requirements and, therefore, acceptable. The Planetary Protection Plan is subject to approval by the Project and concurrence by the relevant Program Office and through established Program Management channels (e.g., Program Executive), as appropriate, prior to its formal submission to the PPO for approval.

## C.4 Later Mission Phases

C.4.1 Following approval of the Planetary Protection Plan by the PPO, the Project embarks on the preparation of subsidiary plans and documentation as detailed in NPR 8020.12, and the implementation of planetary protection requirements consistent with the strategy outlined in the Planetary Protection Plan. Subsidiary plans do not generally require formal approval by the PPO (except all "inbound" subsidiary plans for PP Category V-restricted Earth return missions), but projects are encouraged to develop these plans in consultation with the PPO. Subsidiary plans should be forwarded to the PPO for information and review to ensure consistency with planetary protection requirements and the approved implementation strategy.

C.4.2 The process of implementing planetary protection requirements is subject to monitoring by the PPO. Monitoring activities include informal and formal reviews; witnessing of important implementation activities; reviews of ad hoc analyses; verification assays; and frequent communication. When needed, the project may seek clarification on parameter specifications, negotiate trade-offs, and, if absolutely necessary, request a deviation (with justification) from a particular requirement. It should be noted that approval of such a request does not represent a "waiver" of planetary protection requirements -- rather, the project is granted approval to deviate from the formal requirements by demonstrating that the goals of planetary protection will still be met.

C.4.3 The Project documents implementation activities in the Project's Planetary Protection Pre-Launch Report. This report is to be approved by the Project, with concurrence by the Program Office as appropriate, and submitted to the PPO no later than 90 days before launch. Again, it is strongly encouraged to maintain good communications with the PPO as the report is prepared; to provide a draft to the PPO to ensure the report's adequacy; and to address comments from the PPO before submitting the report for formal approval. Critical events and data collection taking place after the release of the Pre-Launch Report should be communicated to the PPO immediately and included in the informal and formal planetary protection prelaunch reviews that precede the certification by the PPO that the mission has met planetary protection requirements and has PPO approval to launch.

## C.5 Launch and Post-Launch

C.5.1 Activities occurring subsequent to submission of the Pre-Launch Report, along with launch and postlaunch updates, are to be documented in the Project's Planetary Protection Post-Launch Report, submitted to the PPO no later than 60 days after launch. The process for formal approval of this document is the same as that followed for the Planetary Protection Plan and Planetary Protection Pre-Launch Report.

C.5.2 Communications with the PPO continue postlaunch, as necessary, to report on mission operations involved in compliance with planetary protection requirements, including but not limited to the execution of trajectory correction maneuvers, orbit insertion, aerocapture or aerobraking, entry descent and landing, ground operations, etc. Any anomalies or off-nominal events that could affect planetary protection compliance should be reported immediately to the PPO, and an

assessment of their impact on the project's compliance with planetary protection requirements should be provided in a timely fashion. Should compliance be jeopardized, the Project must take appropriate steps, negotiated with the PPO, to ensure that planetary protection requirements are not violated.

C.5.3 For PP Category V-Restricted Earth return missions, added to the outbound requirements are the certifications and documentation detailed in NPR 8020.12, particularly approval of all "inbound" subsidiary plans for PP Category V-restricted Earth return missions. The process of interaction with the PPO for sample return missions otherwise should follow the steps outlined in these guidelines.

## **C.6 Extended Missions**

C.6.1 If the project plans to extend its mission, a letter requesting approval for the extension as well as an Extended Mission Planetary Protection Report should be submitted to the PPO no later than 60 days prior to the end of the nominal mission. Communication with the PPO is necessary to assure that the appropriate information is included in the extension request. The same process must be repeated for each extended mission.

## **C.7 End of Mission**

C.7.1 The final report the Project is required to submit to the PPO, per NPR 8020.12, is the End-of-Mission Planetary Protection Report. Consultation with the PPO may be appropriate to address issues identified during preparation of this report, and it is due no later than 60 days after the formally declared end of mission.

C.7.2 In the unfortunate event of a mission failure, the project is required to submit to the PPO an End of Mission report that includes a comprehensive analysis and assessment of the failure's contribution to the potential contamination of any impacted planet(s).



# Appendix D. Planetary Protection Specification Sheets

## Table of Contents

### Microbiological Standards

#### Clean Room Requirement

Average Encapsulated Microbial Density

Source Specific Encapsulated Microbial Density

Surface Microbial Density

Temperature Dependence of D-Value

D-Value for Microbial Spore Burden on Exposed Surfaces

D-Value for Microbial Spore Burden on Mated Surfaces

D-Value for Encapsulated Microbial Spore Burden

Fraction of Hardy Organisms and their Survival of Nominal Sterilization Cycles

Time-Temperature for Absolute Sterility

Probability of Surface Organisms Surviving Ultraviolet Radiation

### Constraints for Biobarriers

#### **PARAMETER TITLE:** Clean Room Requirement

VALUE		APPLICATION	
UPPER		MISSION	
ACCEPTABLE	Class 100,000	PP CATEGORY	II, III and IV
LOWER		PLANET	All

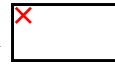
**PARAMETER DEFINITION:** Procedures for spacecraft and payload assembly.

**APPLICABLE SOURCE:** Spacecraft and payloads.

**CONSTRAINTS:** All PP Category II, III and IV missions shall assemble and maintain spacecraft and payloads in Class 100,000 or ISO class 8 cleanrooms in the operational mode (Ref. 1, 2). The class is to be monitored and verified, with the sampling frequency and number of locations per a clean zone as specified in Ref. 1 or 2 for any flight hardware location within the cleanroom. Attendant controls and procedures must be similar to those employed by the Viking Project or Ref. 2. This requirement is independent of any other requirement, e.g., any bioburden limitation.

#### **REFERENCES:**

1. "Clean Room and Clean Work Station Requirements, Controlled Environments", Federal Standard No. 209C, 1987 (or latest revision).
2. "Cleanrooms and associated controlled environments" "Part 1: Classification of air cleanliness," ISO 14644-1, 1999. "Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1," ISO 14644-2, 2000. "Part 5: Cleanroom Operations," ISO 14644-5, 2004.

\_\_\_\_\_  
Planetary Protection Officer\_\_\_\_\_  
Date**PARAMETER TITLE:** Average Encapsulated Microbial Density

VALUE		APPLICATION	
UPPER	130/cm <sup>3</sup>	MISSION	All
ACCEPTABLE	130/cm <sup>3</sup>	PP CATEGORY	III, IV
LOWER	130/cm <sup>3</sup>	PLANET	All

**PARAMETER DEFINITION:** The average density of spores buried inside nonmetallic spacecraft material. This value reflects reductions experienced in the manufacture of the basic material, but it does not account for any burden reduction during higher level assembly and test.

**APPLICABLE SOURCE:** Nonmetallic portions of the spacecraft.

**CONSTRAINTS:** If this parameter is used, it must be applied to the total volume of nonmetallic material and further subdivisions using source-specific density values  $d_v(0)$  shall not be made.

This value was derived assuming the subsequent use of heat sterilization. If processes are proposed that do not include heat for a PP Category IV mission, the value must be reassessed to assure its applicability for the proposed usage. It may be used without restriction for PP Category III mission burden estimates.

**REFERENCES:** Planetary Quarantine Advisory Panel (PQAP) Review, September 28, 1971, Denver, CO

\_\_\_\_\_  
Planetary Protection Officer\_\_\_\_\_  
Date**PARAMETER TITLE:** Source Specific Encapsulated Microbial Density

VALUE		APPLICATION	
UPPER		MISSION	All
ACCEPTABLE	See Below	PP CATEGORY	III, IV
LOWER		PLANET	All

**PARAMETER DEFINITION:** The average number of spores buried inside the *i*th subassembly or component of a spacecraft. The number can be expressed in terms of volume or area according to the application as specified below.

**APPLICABLE SOURCE:** Nonmetallic materials on the spacecraft.

**CONSTRAINTS:** Source-specific density values can be used only if applied to the entire volume of spacecraft non-metallic material without resorting to the average density value,  $d_v(0)$ , for any portion thereof. Values for this parameter must be derived for all applicable sources. Values are

selected from the following categories and ranges depending upon the composition of, and manufacturing process for, each designated source:

Encapsulated Organisms in:	<input type="checkbox"/>
Electronic piece parts	3-150/cm <sup>3</sup>
Other nonmetallic materials	1-30/cm <sup>3</sup>
Enclosed surface densities:	
Cleanroom-highly controlled	0.05-0.5cm <sup>2</sup>
Cleanroom-normal control	0.5-10/cm <sup>2</sup>
Uncontrolled manufacturing	10-100/cm <sup>2</sup>

In the use of this parameter, a rationale shall be presented for the selection of values less than the maximum of the applicable range specified. This value was derived assuming the subsequent use of heat sterilization. If processes are proposed that do not include heat for a PP Category IV mission, the value must be reassessed to assure its applicability for the proposed usage. It may be used without restriction for PP Category III mission burden estimates.

**REFERENCES:** PQAP Review, September 28, 1971, Denver, Colorado.

\_\_\_\_\_  
 Planetary Protection Officer

\_\_\_\_\_  
 Date

**PARAMETER TITLE:** Surface Microbial Density (d<sub>s</sub> (0))

VALUE		APPLICATION	
UPPER		MISSION	All
ACCEPTABLE	See Below	PP CATEGORY	III, IV
LOWER		PLANET	All

**PARAMETER DEFINITION:** The average number of spores on any free surface (nonencapsulated) of a spacecraft system, subsystem, assembly, or subassembly.

**APPLICABLE SOURCE:** All fallout burden on the spacecraft (exposed and mated).

**CONSTRAINTS:** Values of this parameter are selected from the following categories, depending on the manufacturing process and cleaning and contamination control procedures for the designated hardware:

Cleanroom 10 <sup>4</sup> or better - highly controlled	50/m <sup>2</sup>
Cleanroom 10 <sup>4</sup> - normal control	5x10 <sup>2</sup> /m <sup>2</sup>
Cleanroom 10 <sup>5</sup> - highly controlled	1x10 <sup>3</sup> /m <sup>2</sup>
Cleanroom 10 <sup>5</sup> - normal control	1x10 <sup>4</sup> /m <sup>2</sup>

Uncontrolled manufacturing

 $1 \times 10^5/m^2$ 

For estimating surface densities for vegetative microorganisms (for purposes other than to establish terminal sterilization cycles), multiply the above values by a factor of 10.

\_\_\_\_\_  
Planetary Protection Officer\_\_\_\_\_  
Date**PARAMETER TITLE:** Temperature Dependence of D-Value , Z

VALUE		APPLICATION	
UPPER	21C	MISSION	All
ACCEPTABLE	21C	PP CATEGORY	IV
LOWER	21C	PLANET	All

**PARAMETER DEFINITION:** The change in temperature which produces a factor of 10 change in a given D-value.

**APPLICABLE SOURCE:** All microbial burden subjected to dry heat sterilization cycles.

**CONSTRAINTS:** Applicable within the temperature range of 104C to 125C. Applicable to dry heat sterilization cycles, meeting requirements of NPR 8020.12D.

**REFERENCES:**

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

\_\_\_\_\_  
Planetary Protection Officer\_\_\_\_\_  
Date**PARAMETER TITLE:** D-Value for Microbial Spore Burden on Exposed Surfaces (DS<sub>125</sub>)

VALUE		APPLICATION	
UPPER	0.5 hr.	MISSION	All
ACCEPTABLE	0.5 hr.	PP CATEGORY	IV
LOWER	0.5 hr.	PLANET	All

**PARAMETER DEFINITION:** Time required to destroy 90 percent of the nonhardy microbial spore population on surfaces subjected to sterilizing dry heat at a temperature of 125C at an absolute humidity corresponding to a relative humidity of less than 25 percent referenced to the standard conditions of 0C and 760 torr pressure.

**APPLICABLE SOURCE:** All nonhardy microbial spore populations located on spacecraft "free" surfaces (i.e., such that gas exchange can take place).

**CONSTRAINTS:** Specified D-value can be applied where sterilization cycle conditions stated in NPR 8020.12D have been met. Thermal response of materials must be considered in design of

sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

**REFERENCES:**

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

---

 Planetary Protection Officer

---

 Date
**PARAMETER TITLE: D-Value for Microbial Spore Burden on Mated Surfaces (D<sub>M125</sub>)**

VALUE		APPLICATION	
UPPER	1.0 hr.	MISSION	All
ACCEPTABLE	1.0 hr.	PP CATEGORY	IV
LOWER	1.0 hr.	PLANET	All

**PARAMETER DEFINITION:** Time required to destroy 90 percent of the nonhardy microbial spore population on mated surfaces of spacecraft subjected to sterilizing dry heat at a temperature of 125C at an absolute humidity corresponding to a relative humidity of less than 25 percent referenced to the standard conditions of 0C and 760 torr pressure.

**APPLICABLE SOURCE:** All nonhardy spore populations on mated surfaces of spacecraft.

**CONSTRAINTS:** Specified D-value can be applied where sterilization cycle conditions stated in NPR 8020.12D have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

**REFERENCES:**

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

---

 Planetary Protection Officer

---

 Date
**PARAMETER TITLE: D-Value for Encapsulated Microbial Spore Burden (D<sub>B125</sub>)**

VALUE		APPLICATION	
UPPER	5.0 hr.	MISSION	All
ACCEPTABLE	5.0 hr.	PP CATEGORY	IV
LOWER	5.0 hr.	PLANET	All

**PARAMETER DEFINITION:** Time required to destroy 90 percent of the nonhardy microbial spore population encapsulated in nonmetallic spacecraft material subjected to sterilizing dry heat at a temperature of 125C.

**APPLICABLE SOURCE:** All nonhardy spore populations buried within nonmetallic spacecraft

materials.

**CONSTRAINTS:** Specified D-value can be applied where sterilization cycle conditions stated in NPR 8020.12D have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

**REFERENCES:**

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

---

Planetary Protection Officer

---

Date

---

**PARAMETER TITLE:** Fraction of Hardy Organisms and their Survival of Nominal Sterilization Cycles ( $N_H/N_0$ )

VALUE		APPLICATION	
UPPER	$1 \times 10^{-3}$	MISSION	Any Requiring Sterilization
ACCEPTABLE	See Below	PP CATEGORY	IV
LOWER	$1 \times 10^{-4}$	PLANET	All

**PARAMETER DEFINITION:** Hardy (heat resistant) organisms as a fraction of the total spore population on spacecraft surfaces. Survival of the hardy organisms is expressed as the ratio of the hardy organisms surviving a nominal sterilization cycle to the initial presterilization total spore population.

**APPLICABLE SOURCE:** All microbial spore populations located on spacecraft surfaces.

**CONSTRAINTS:** Hardy organisms comprise a fraction of  $1 \times 10^{-3}$  of the total spore population on spacecraft surfaces. For nominal sterilization cycles, i.e., 35-50 hours at temperatures of 111 - 125°C, the surviving fraction of hardy organisms is  $1 \times 10^{-4}$ . Therefore, in designing or assessing spacecraft sterilization cycles, the logarithmic death-rate model based on the D and Z values provided elsewhere in this specification book should not be used to predict lethality greater than  $1 \times 10^{-3}$  for microbial spore populations on spacecraft surfaces. The model is valid, however, for calculating lethality up to the level of the hardy surviving fraction, which, at  $1 \times 10^{-4}$ , establishes the maximum allowable lethality for the nominal sterilization cycles described above.

**REFERENCES:**

1. Thermal Resistance of Naturally Occurring Airborne Bacterial Spores. J. R. Puleo, et al., Planetary Quarantine Laboratory, Jet Propulsion Laboratory, Cape Canaveral, FL, 1978.
2. Statistics of the  $N_H/N_0$  Ratio. Paper presented at the "Hardy" Organisms conference, Ames Research Center, November 1974, by P.D. Stabekis, Exotech Research & Analysis, Inc., Gaithersburg, MD.

---

Planetary Protection Officer

---

Date

---



**PARAMETER TITLE:** Time-Temperature for Absolute Sterility (K (†T))

VALUE		APPLICATION	
UPPER	$\geq 0.5$ sec @ $\geq 500C$	MISSION	All
ACCEPTABLE	Same	PP CATEGORY	All
LOWER	Same	PLANET	All

**PARAMETER DEFINITION:** The short time-high temperature conditions at which all organisms will be completely destroyed.

**APPLICABLE SOURCE:** Any source of terrestrial organisms associated with spacecraft hardware. Sources can be encapsulated, mated surface, open surface or airborne. The temperature must exist at the location of the microbial burden for the required time duration.

**CONSTRAINTS:** Spacecraft organisms and their associated environment must reach a temperature of at least 500C and must remain at this temperature for at least one half second. This specification was derived from high temperature sterilization tests of microbial contamination.

**REFERENCES:**

- Hoffman, R. K., et al. Thermal Inactivation of Aerosolized Bacillus subtilis var. niger Spores. Appl. Microbiol. 22(4): Oct. 1971.
- Recommendations of PQAP, meeting held Feb. 1, 1973, New Orleans, LA.

---

 Planetary Protection Officer

---

 Date
**PARAMETER TITLE:** Probability of Surface Organisms Surviving Ultraviolet Radiation (P (uv))

VALUE		APPLICATION	
UPPER	1	MISSION	All
ACCEPTABLE	See Below	PP CATEGORY	IV
LOWER	$< 10^{-4}$	PLANET	All

**PARAMETER DEFINITION:** Probability that a randomly selected organism exposed to extraterrestrial ultraviolet radiation will survive the dose applicable to the mission specific conditions.

**APPLICABLE SOURCE:** All organisms exposed to extraterrestrial ultraviolet radiation.

**CONSTRAINTS:** Selection of a particular value is to be made in two steps as follows:

1. Assuming complete exposure of the microorganisms, i.e., no shielding, P(uv) is determined by the function described below. The value of P(uv) as a function of time is a straight line on a log-log scale. For Martian missions, the line is defined by the following two points:

- (a) P(uv) = 1 for a time of exposure of 1 minute, or less, and

(b)  $P(uv) = 1 \times 10^{-4}$  for a time of exposure of 1 hour.

$P(uv)$  for times of exposure other than the above can be obtained by interpolation or extrapolation of these two points. For distances other than for Mars (1.5A.U.), the time of exposure needed shall be scaled by an inverse square relationship.

2. The value obtained in accordance with the above must be increased to allow for the effects of shielding by structures or by small particles such as dust and debris.

REFERENCES: PQAP Review on January 18-19, 1972, at Cape Canaveral, FL.

\_\_\_\_\_  
Planetary Protection Officer

\_\_\_\_\_  
Date

**PARAMETER TITLE: Constraints for Biobarriers**

(1) Microbial barriers that are continuously maintained at a static pressure of at least 1244 Pascals (9.3 Torr; 5 inches of H<sub>2</sub>O) above the ambient pressure shall be considered microbiologically sealed. For sample handling systems, lower-pressure differentials may be employed for biological safety cabinets per the regulations of the U.S. Centers for Disease Control and Prevention (Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets. 2nd Ed.2000. <http://www.cdc.gov/od/ohs/biosfty/bsc/bsc.htm>).

(2) Microbial barriers that operate essentially at ambient pressure through the use of microbial filters shall be considered microbiologically sealed if the following occur:

(i) The designs of all filter mountings, barrier joints, seals etc., have been tested in accordance with applicable design and test specifications and found capable of retaining 99.97 percent of all particles or organisms greater than 0.3 um in size.

(ii) The filters are High Efficiency Particulate Air Filters ("HEPA Filters") capable of removing 99.97 percent of all particles greater than 0.3 um in size.

(iii) All elements of the filter system are procured, installed, tested, inspected, and maintained using appropriate quality assurance provisions.

\_\_\_\_\_  
Planetary Protection Officer

\_\_\_\_\_  
Date