NASA Interim Directive (NID)

Effective Date: December 5, 2016

Planetary Protection Provisions for Robotic Extraterrestrial Missions
Responsible Office: Science Mission Directorate

TABLE OF CONTENTS

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) to fulfill his/her responsibilities pertaining to planetary protection, as required by NID 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 NID is applicable to NASA Headquarters and NASA Centers, including Component Facilities and Technical and Service Support Centers. This language applies to JPL, 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 NID 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 Shuttle-launched, but otherwise robotic, planetary missions.

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. National Aeronautics and Space Act of 1958, as amended, 51 U.S.C. § 2473 (c) (l).

b. NPR 8020.7 Biological Contamination Control for Outbound and Inbound Planetary Spacecraft.

P.4 APPLICABLE DOCUMENTS AND FORMS

a. Committee on Space Research (COSPAR) Planetary Protection Policy, as amended.

b. NPR 7120.5, NASA Spaceflight Program and Project Management Requirements.

c. NASA HDBK 6022, NASA Standard Procedures for the Microbial Examination of Space Hardware.

P.5 MEASUREMENT/VERIFICATION

a. To ensure compliance with this NID, the Planetary Protection Officer (PPO) monitors the PP-related activities and development of required documentation, specified in this document, by individual missions, and recommends approval or non-concur to the SMD AA for the final gate products identified in this document at Key Decision Points (KDPs), by review of of milestone products and control plans due at life-cycle reviews. Signed and approved documents are to be completed in association with Key Decision Points as described in this document and NPR 7120.5.

b. Project compliance with requirements described in this NID are subject to verification by the PPO per their insight role, 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

None

CHAPTER 1. Planetary Protection Categorization of Missions

1.1 Overview

Planetary Protection involves protecting the planet we are visiting and protecting the Earth from harmful organic or biological elements when we return samples or contaminated spacecraft or astronauts; and is the responsibility of the Planetary Protection Officer.

Mission Science integrity is the responsibility of the science community, which involves maintaining cleanliness levels required to achieve the science investigation including when samples are returned to Earth.

1.1.1 Each planetary mission will fall into one or more categories based on the planetary protection priorities of each extraterrestrial solar system body and the mission plan. Planetary protection priorities and corresponding mission categories are given in Table 1. Each category has different planetary protection requirements, as described in Chapter 2 of this document. Mission categorization is determined by the Planetary Protection Officer (PPO), upon request from the flight project as specified in section 2.1.2 and final resolution documented in the PLRA.

Table 1. Planetary Protection Mission Categories

Planetary Target Priority	Mission Type	Mission Category
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 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 NPR 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 Waivers and Deviations

1.3.1 Planetary protection requirements shall be met at all times unless a waiver is approved by the SMD AA.

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

CHAPTER 2. General Mission Requirements

2.1 NASA Missions

2.1.1 Specific planetary protection categorization requirements for each planned mission are determined by the NASA PPO, in accordance with this document.

2.1.2 Requests for categorization of missions and associated mission requirements is submitted to the PPO by the mission Project Manager or Principal Investigator, preferably before the end of Pre-Phase A.

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 categorization should be included, and a category-specific listing of target body/mission types is provided in Appendix C for guidance in preparing this request. The PPO will respond in writing with the appropriate categorization, conveying such explanatory information or supplemental conditions as may be appropriate. Final resolution will be documented in the PLRA

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 described in NPR 7120.5E. Approval of a mission's Planetary Protection Plan, for missions above Category I, will complete formal categorization of the mission, and should be completed no later than the end of Phase B.

2.2 NASA Participation in non-NASA or non-U.S. Missions

2.2.1 The mission PP categorization and certification of compliance shall be the sole responsibility of the lead and launching organization(s).

2.2.3 Instrument projects anticipating flights on non-NASA spacecraft may receive preliminary guidance by submitting a request to the NASA PPO, outlining the nature of the instrument(s) to be flown and details of the anticipated flight opportunity. PP requirements shall be as provided by the PPO (or equivalent authority) of the lead and launching organization(s).

2.4 During development and delivery of the instruments/experiments, monitoring of the implementation and certification of PP requirements shall be the responsibility of the lead and launching organization(s).

2.3 Implementation Requirements for U.S. Missions

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

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

b. 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 Category II are listed in Appendix C.

c. Category III Missions: Planetary protection requirements consist of documentation as detailed in section 2.7 (more involved than 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 Category III are listed in Appendix C. Detailed requirements and associated specification sheets for Category III missions to selected solar system bodies are set forth in Appendices C and E, respectively.

d. Category IV Missions: Planetary protection requirements include detailed documentation, listed in Section 2.7 (more involved than Category III), review requirements in section 2.8, and 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 a bioshield 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 Category IV are listed in Appendix C. Detailed requirements and associated specification sheets for Category IV missions to selected solar system bodies are set forth in Appendices C and E, respectively.

e. Category V Missions: This 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. 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 category of that phase (typically Category I or II). Restricted Earth Return missions have PP requirements that encompass those for 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 Category V requirements for selected solar system bodies are included in Appendix C.

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

Mission Category	Implementation Requirements
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 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, pre-project advanced studies and research, as needed).

2.3.2 Requests for categorization as "Unrestricted Earth Return" or "Restricted Earth Return" shall be submitted to the PPO when mission categorization is requested. After discussion and review, a memorandum will be submitted by the PPO to the Associate Administrator for the SMD requesting the appropriate certification for the mission. Final categorization level will be documented in the PLRA, which is approved by the SMD AA.

2.3.3 For Category V missions designated as "Restricted Earth Return," an extensive set of additional documentation, detailed in section 2.7, is required to ensure that the Earth's biosphere is not adversely affected by the introduction of returned samples.

a. 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.

b. After the flight mission there is a need to conduct, under strict containment and using the most effective 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 concurrence and SMD AA for approval. When planetary protection is referenced in other project documentation, those documents shall be made available for the PPO to review. A summary of planning and documentation requirements by mission 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 Category

Mission Category	Planning and Documentation
I	Certification of 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 Organics Inventory (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 Organics Inventory (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 Planetary Protection Implementation Plan Pre-Return Planetary Protection 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 SMD AA approval according to the schedule in Table 4, to be coordinated with KDP requirements given in NPR 7120.5. It is intended that the established dates be designated "control items" to be reported in the monthly Project Management Reports. The exact dates consistent with the schedule will be determined in a manner agreeable to both PPO and Project Management and will be documented in the Planetary Protection Plan.

Table 4. Planetary Protection Documentation Schedule

Report	Required Schedule
Mission Categorization	Request for preliminary categorization to PPO during pre-Phase A/Phase 0. Request for formal categorization to PPO no later than start of Phase A.
(If applicable) Certification for "Unrestricted Earth return"	*No later than the end of Phase A.*
Planetary Protection Plan	Project-approved draft complete no later than end of Project's Conceptual Study Phase (Phase B). Release before the Project's Preliminary Design Review (PDR).
PP Implementation Plan	Project-approved draft complete before the project's Critical Design Review (CDR).
Subsidiary Plans	Project-approved draft no later than 3 months after completion of draft Planetary Protection Plan. Release of all Subsidiary Plans before the Project's CDR.
Pre-Launch PP Report	No later than 90 days prior to the scheduled launch.
Extended Mission PP Report	No later than 60 days prior to scheduled end

	of the mission per the Planetary Protection Plan.
Post-Launch PP Report	No later than 60 days after actual launch.
Earth Pre-Return Report	*Release prior to the Earth Return Pre-Launch Review.*
Earth Pre-Entry Report	*Release prior to the Earth Safety Analysis Review.*
End-Of-Mission	No later than 60 days after the formally declared "End-of-Mission."
Sample Pre-Release Report (may be released in sections)	*Release prior to the Returned Sample Release Review and any release of sample material.*

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

Review	Schedule
Planetary Protection Plan	Review within 60 days of draft release.
Subsidiary Plans	Review within 60 days of draft release.
Pre-Launch PP Review	No later than 90 days or earlier than 120 days prior to earliest scheduled launch date.
Launch Readiness Review	Project scheduled review.
Earth Return Pre-Launch Review	No earlier than 30 day or later than 7 days prior to earliest scheduled return launch date.
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 (maybe done in separate segments)	Following completion of the life detection and 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 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 shall be permitted only after review and approval by the PPO.

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 and SMD AA 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 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 Category V require approval by the Associate Administrator of SMD.

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

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

a. Category I missions:

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

requirements.

b. 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. 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. 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. Category V missions. Missions categorized as "Unrestricted Earth return" have no additional return phase requirements (see above). Missions categorized 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 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 pre-launch 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 Category II or higher shall provide the following planetary protection

documentation, tailored appropriately to the mission category. Planning and documentation requirements for the return leg of Category V missions, including subsidiary plans, are described separately in section 2.7.4.

2.7.3.1 Planetary Protection Plan (Categories II-V)

a. The Planetary Protection Plan shall be prepared according to the schedules outlined in section 2.5. 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. 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, it is suggested that the Planetary Protection Plan include only the major aspects of the topic and that free reference be made to the basic project documents that provide specificity.

b. 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 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

c. The following paragraphs modify specific Category II-V Mission Planning and Documentation requirements.

(1) For 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.

(2) For 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 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.

(3) For 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.

2.7.3.2 Subsidiary Implementation Plans (Categories III-V)

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

(1) Contamination Analysis Plan
(2) Microbiological Assay Plan
(3) Microbial Reduction Plan

(1) Contamination Analysis Plan

(a) This document is 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.

(b) 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

(2) Microbiological Assay Plan (Categories IV and III, for orbiters meeting the bioburden requirement)

(a) The Microbiological Assay Plan shall identify the space vehicle hardware, facilities, and associated environments which are subject to microbiological assay and describe the rationale, concepts, and detailed procedures pertaining to such assays. The plan also describes the microbiological quality assurance procedures used to ensure validity of the assay results.

(b) The plan shall include, but not be 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

(3) Microbial Reduction Plan (Categories IV and III, for orbiters meeting a bioburden

requirement)

(a) 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.

(b) The Microbial Reduction Plan shall include, but not be 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

2.7.3.2 Planetary Protection Implementation Plan (Categories III-V)

a. The PP Implementation Plan is the reference document that describes in detail the processes, procedures, analyses, and facilities that are used to implement the Planetary Protection Plan and subsidiary plans.

2.7.3.3 Pre-Launch Planetary Protection Report (Categories II-V)

a. 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.

b. This document shall include, but not be limited to, the following information. This information may be included as a part of the document or referenced in the document. Reference documents may be submitted to the PPO as they are published.

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

(2) Identification of all approved planetary protection deviations (see 2.4) from the Planetary Protection Plan.

(3) 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.

c. Mission Category Specific Requirements

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

(2) For Category III missions, the following information shall be provided:

(a) Calculations of microbial burden estimates.
(b) Report on required contamination control measures.
(c) Calculations of probability of impact.
(d) Organic materials inventory.

(3) 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.

(4) For Category IV missions, the requirements include the same information as for Category III. Additionally, information must be provided detailing the microbial reduction procedures employed and documentation supporting the results of the process.

2.7.3.4 Post-Launch Planetary Protection Report (Category II-V)

a. After the launch of a planetary vehicle, the flight project 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 updated to include the effects of launch and early post-launch events. It must demonstrate compliance with the overall planetary protection requirements through these early mission events.

2.7.3.5 End-of-Mission Report (Category II-V)

a. At the formally declared "end-of-mission," a report shall be provided 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. For the record, the report must also 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 all Category II and III missions, an inventory of organic materials must also be provided in the End-of-Mission Report for any spacecraft hardware, which unintentionally impacted or will impact any solar system body within 50 years after launch.

2.7.4 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 Earth Safety Analysis Plan

a. The Earth Safety Analysis Plan shall be 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 includes, 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 Earth Pre-Return Report

a. The "Earth Pre-Return Report" is a document patterned after the Planetary Protection Plan used by a flight project and 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.

2.7.4.3 Earth Pre-Entry Report

a. 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 post-launch events, and demonstrates how the mission meets the overall planetary protection requirements.

2.7.4.4 End-of-Mission Report

a. In addition to the information provided consistent with outbound phase requirements, at the formally declared "end-of-mission," a report shall be provided 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.

2.7.4.5 Sample Pre-Release Report

a. 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 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 must include the reviews listed in Table 5. Additional formal and informal reviews may be held as warranted and as requested and agreed to 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

Mission Category	Required Review
I (Any)	None
II (Any)	Project PP Review (PPO Option)

III (Flyby, Orbiter)	1. Project Planetary Protection Planning 2. Pre-Launch Planetary Protection Review 3. Launch Readiness Review
IV (Lander, Probe)	1. Project Planetary Protection Planning Review 2. Pre-Ship Planetary Protection Review 3. Pre-Launch Planetary Protection Review 4. Launch Readiness Review
V "Unrestricted Earth Return"	No further reviews beyond those for the outbound phase of the mission, as appropriate (see Categories I-IV)
V "Restricted Earth Return"	1. Project Planetary Protection Planning Review 2. Pre-Ship Planetary Protection Review 2. Pre-Launch Planetary Protection Review 3. Launch Readiness Review 4. Earth Return Pre-Launch Review 5. Earth Safety Analysis Review 6. Returned Sample Release Review

2.8.3 Planetary protection reviews shall cover the following information:

2.8.3.1 Project Planetary Protection Planning Reviews (Categories II-V)

a. At the request of either the PPO or the project's authorized representative, a Planetary Protection Planning Review may be held 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.

b. The content of these reviews shall be developed in discussions between the PPO and various organizational elements of the project. Action items which may result from these reviews must 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. 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 categorization of the mission for planetary protection purposes.

2.8.3.2 Pre-Ship Planetary Protection Review (Categories III-V)

This review shall be conducted prior to the shipment of the spacecraft to the launching site (for most NASA missions, this would be the NASA Kennedy Space Center). 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 Pre-Launch Planetary Protection Review (Categories III-V)

Approximately ninety days prior to launch, a "Pre-Launch Planetary Protection Review" shall be conducted for all missions assigned to 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 2.7.3.3) forms the framework for this review.

2.8.3.4 Launch Readiness Review (Categories III-V)

Various events detrimental to planetary protection could occur subsequent to the Pre-Launch Planetary Protection Review and prior to actual launch of the vehicle. In order to ensure that planetary protection requirements continue to be met, the PPO (or designated alternate) shall participate in the project's formal Launch Readiness Review, the agenda of which includes planetary protection as a topic. 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 Earth Return Pre-Launch Review (Category V, "Restricted Earth Return")

Prior to launch of the Earth return portion of a Category V mission, an Earth Return Pre-Launch Review shall be conducted for all missions assigned to Category V. The PPO conducts this review to ascertain that 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 formally released edition of the "Earth Pre-return Report" (see section 2.7.4.2) forms the framework for this review.

2.8.3.6 Earth Safety Analysis Review (Category V, "Restricted Earth Return")

Prior to committing a spacecraft to the Earth return portion of its mission, the PPO shall conduct an Earth Safety Analysis 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 2.7.4.3), forms the framework for this review. This review may be attended by the Associate Administrator of SMD and members of the 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 Returned Sample Release Review (Category V “Restricted Earth Return”)

Prior to release of an extraterrestrial sample, or portions of the sample, for study elsewhere, the PPO shall conduct a returned Sample Release Review. This review is 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 2.7.4.4), or an appropriate section of that report, forms the framework for the

review. This review should definitely be attended by members of the Interagency Committee and by the Associate Administrator of SMD, whose approval must be obtained before release of the samples.

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 demonstrate 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 by the start of 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 E.

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

3.2.2 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 2.5) shall be conducted for the PPO by an organization designated by the PPO. Verification assays may be observed by involved flight project and contractor organizations.

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 that data are suspect due to possible laboratory contamination, an Assay Review Board, appointed by the PPO, shall be formed to review the suspect data and their causes.

3.3.3.1 The Board shall be chaired by a designee of the PPO, with members representing both the organization conducting the assay and the involved flight project, and other members as appropriate to provide technical adjudication of the matter.

3.3.3.2 The Board shall present its findings and conclusions to the PPO together with appropriate recommendations.

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.

> *Note: Currently, the only a priori approved method for actively reducing spacecraft to near sterility levels is through the application of dry heat per the appropriate specifications in Appendix D.*

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 E).

3.4.3 The specification of basic microbial reduction parameters shall be made in one or more of (1) the Microbial Reduction Plan, (2) Parameter Specification Sheets, or (3) 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 (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 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.

3.5.1.2 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 post-launch 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.

4.2 Delegated Responsibilities of the Planetary Protection Officer

4.2.1 The responsibilities delegated by the Associate Administrator for the Science Mission Directorate to the PPO are identified in NPD 8020.7. In discharging those responsibilities, the PPO shall:

a. Represent the Associate Administrator for the Science Mission Directorate 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 Committee on Space Research of the International Council for Science.

b. Establish planetary protection requirements applicable to each planetary flight program/project consistent with requirements herein, and establish methods to verify that planetary protection requirements have been met.

c. 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, 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. Providing insight 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. Establishing and supporting research and technology development so that state-of-the-art methodologies are incorporated into the implementation of planetary protection policy.

CHAPTER 5 Detailed Planetary Protection Requirements

5.1 Numerical Implementation Guidelines for Forward Contamination Calculations not otherwise specified

5.1.1 To the degree that numerical guidelines are required to support the overall policy objectives of this document, and except where numerical requirements are otherwise specified, the guideline 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 $1x10^{-3}$. No specific format for probability of contamination calculations is specified.

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

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

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

5.2.2 Category II (Flyby, Orbiter, Lander): Venus; Moon (with organic inventory); Comets; most Asteroids; Jupiter; Jovian Satellites except Io, Ganymede*, and Europa; Saturn; Saturnian Satellites except Titan* and Enceladus; Uranus; Uranian Satellites; Neptune; Neptunian Satellites except Triton*; Pluto*/Charon*; Kuiper-Belt Objects <1/2 the size of Pluto; other TBD.

5.2.2.1The mission-specific assignment of *star bodies 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 < 1x10-4 of introducing 1 viable terrestrial microorganism), addressing both the existence of such environments and the prospects of accessing them.

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

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

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

5.3 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 80°C for 15 minutes and are cultured on TSA at 32°C for 72 hours (hereinafter "spores").

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

5.3.1.1 A probability of impact assessment shall be provided for all launch vehicle elements leaving Earth orbit for the first fifty years after launch. Launch vehicles shall meet a probability of impact of 10^{-4} for fifty years.

5.3.1.2 Cruise stages, flyby, and orbiter spacecraft shall meet a probability of impact of 0.99 for twenty years after launch and a probability of impact of 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.

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

5.3.2 Category IV for Mars is subdivided into IVa, IVb, and IVc. Missions shall comply with requirements appropriate to the subcategory they have been assigned.

5.3.2.1 Category IVa. Lander systems not carrying instruments for the investigations of extant martian life shall be restricted to a surface biological burden level of $\leq 3 \times 10^5$ spores, and an average of ≤ 300 spores per square meter.

a. An assessment of the probability of a non-nominal landing (including EDL) shall be provided.

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

a. The entire landed system is restricted to a surface biological burden level of ≤ 30* spores, or to levels of biological burden reduction driven by the nature and sensitivity of the particular life-detection experiments, and protected from recontamination.

OR

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

c. An assessment of the probability of a non-nominal landing (including EDL) shall be provided.

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

a. Case 1. If the landing site is within the special region, the entire landed system shall be restricted to a surface biological burden level of ≤ 30* spores.

b. Case 2. If the special region is accessed though horizontal or vertical mobility, the requirement shall be either the entire landed system is restricted to a surface biological burden level of ≤ 30* spores, OR the subsystems which directly contact the special region must be sterilized to these

levels, and a method of preventing their recontamination prior to accessing the special region be provided.

5.3.2.3.1 If the probability of a non-nominal landing in a special region (including EDL) is greater than 0.01, then the entire landed system shall be sterilized to Viking post-sterilization levels: a surface biological burden level of ≤ 30* spores and a total (surface, mated, and encapsulated) bioburden level of ≤ 1.5×10^4 spores*.

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

5.3.2.3.2 A Special Region is 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; Upper limit: 1.0
(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.

5.3.2.4 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 (Kminek et al., 2008)

5.3.3 Category V. The Earth return portion of a Mars Sample Return mission is classified as "Restricted Earth return." 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 Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later Mars missions.

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 re-entry.

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 Construction and commissioning of a sample-receiving facility shall be completed and fully operational at least 2 years prior to the return of samples to Earth, in order to allow ample time for integrated testing of the facility, the overall test protocol, and instrumentation well in advance of receiving returned martian materials.

5.3.3.10 A sample-receiving facility shall employ multidisciplinary teams of scientists to develop, validate, and perform a rigorous battery of tests 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 Category II*/III/IV Requirements for Icy Satellites

C.4.1 Category II*, III and IV. 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 1×10^{-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 Category III orbiters as well as for 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 bio load and its microbial diversity, including specific problematic species (SSB 2000).

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

5.4.3.6 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 the target for return to Earth; and 3) prior to commitment to Earth re-entry.

5.4.3.7 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 (SSB 1998).

5.5 Requirements for Small Solar System Bodies

5.5.1 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 Categories I or II. Further elaboration of this requirement is anticipated.

5.5.2 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 CO2 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., <160 C)?

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 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 "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 re-entry.

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 (SSB 1998).

5.6 Additional Implementation Guidelines for Category V Missions

5.6.1 If, during the course of a Category V mission there is a change in the circumstances that led to its classification, or a mission failure, then the sample to be returned shall be abandoned, and if already collected the spacecraft carrying the sample must not be allowed to return to the Earth or the Moon.

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 Biological Monitoring. The data management and visual surveillance activities that are performed so that the microbial burden of an item of interest may be verified.

A.3 Constraints. Bounding conditions governing aspects of the implementation of planetary protection requirements.

A.4 Encapsulated (or Embedded) Bioburden. Microbial burden buried inside nonmetallic spacecraft material.

A.5 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.6 Mated Surfaces. Surfaces joined by fasteners rather than by adhesive.

A.7 Microbial Barrier or Bio barrier. A means to protect a spacecraft or associated component(s) against microbial recontamination following the application of microbial reduction procedures.

A.8 Microbial Bioburden (also referred to as "Biological Burden" or "Bioburden"). The level of microbial contamination (total number of microbes, spores and non-heat shocked, or microbial density) in or on an item of interest.

A.9 Microbial Bioburden Density. Surface burden density-number of microbes per unit surface area. Volume bioburden density-number of microbes per unit volume (of non-metallic material).

A.10 Microbial Monitoring. The collection, analysis, and associated activities that are performed to verify the biological condition of an item of interest.

A.11 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.12 Organics Archive. A stored collection of bulk organic constituents (materials) of all launched hardware.

A.13 Organics Inventory. An itemized list of bulk organic materials used in launched hardware.

A.14 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.15 Planetary Protection. The protection of a planet from terrestrial contaminants and the protection of the Earth's biosphere from potentially harmful extraterrestrial material.

A.16 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.17 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.18 Terminal Microbiological Assay. The last assay done prior to terminal sterilization.

A.19 Terminal Sterilization. A final sterilization process applied to the entire spacecraft system.

A.20 Total Microbial Bioburden. Total of exposed, mated, and encapsulated microbial burden.

A.21 Verification Assay. A microbiological assay performed as requested and directed by the PPO to verify compliance with planetary protection requirements.

APPENDIX B. Acronyms

COSPAR – Committee on Space Research
NPD – NASA Policy Directive
NPR – NASA Procedural Requirements
PP – Planetary Protection
PPO – Planetary Protection Officer or designee

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

C.1 Introduction

D.1.1 NASA's formal Planetary Protection Policy and requirements documents, NID 8020.7 and NID 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 NID 8020.7 and NID 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 Pre-project Phase

D.2.1 Missions can benefit from communication with the PPO at NASA Headquarters even during pre-project 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 categorization letter may be required by specific AO language. Prior to 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 either PM or PI, for PI-led missions) must 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 Categorization Letter from the PPO, the Project must submit a Planetary Protection Plan, unless the project received a 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 Category II missions, as well as 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 PPO is encouraged.

C.3.3 For missions assigned Categories III, IV, and V-restricted Earth return, preparation of the Project's Planetary Protection Plan is significantly more involved and complex, progressively so for the three categories. Development of such a Planetary Protection Plan requires frequent interaction with the PPO, the extent of which will depend on the 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 NID 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 Category V-restricted Earth return missions), but projects are encouraged to develop these plans in consultation with the PPO. Subsidiary plans must 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 pre-launch reviews that precede the certification by the PPO that the mission has met planetary protection requirements and is cleared for launch.

C.5 Launch and Post-Launch

C.5.1 Activities occurring subsequent to submission of the Pre-Launch Report, along with launch and post-launch 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 post-launch, 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, aero capture or aero braking, 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 Category V-Restricted Earth return missions, added to the outbound requirements are the certifications and documentation detailed in NID 8020.12, particularly approval of all "inbound" subsidiary plans for 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 NID 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