General

# Planetary Protection Program Standard

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Japan Aerospace Exploration Agency

This is an English translation of JMR-014A, “Planetary Protection Program Standard”, and does not constitute itself.
Whenever this document conflicts with the original document in Japanese, the original document takes precedence.



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2-1-1 Sengen Tsukuba-shi, Ibaraki 305-8505, Japan

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# 1 GENERAL

## 1.1 Introduction

In 1958, the year after Sputnik, the National Research Council (NRC) of the US National Academy of Sciences (NAS) expressed its deep concern that initial exploration of the Moon and other celestial bodies might compromise future scientific exploration. The Council recommended to plan and conduct Solar system exploration so as to prevent their contamination. The resolution of the NRC was communicated to the Bureau of the International Council of Scientific Unions (ICSU). The ICSU formed an ad-hoc Committee on Contamination by Extraterrestrial Exploration (CETEX) and issued the first code of conduct for planetary protection in the autumn of 1958. The report was endorsed by the NAS Space Studies Board (SSB) and contained the recommendation that the newly established Committee On Space Research (COSPAR) of the ICSU should assume responsibility for matters of planetary protection. The first spaceflight missions to use planetary protection requirements were the Ranger missions in 1961. Since then, all planetary missions had to implement planetary protection measures at different degrees – ranging from simple documentation to terminal sterilization of entire flight systems. The legal basis for planetary protection was established in Article IX of the United Nations Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies (Outer Space Treaty).

The basic goals of planetary protection have remained unchanged:

・to preserve planetary conditions for future biological exploration, and

・to protect Earth and its biosphere (including the Moon) from potential harmful extraterrestrial sources of contamination.

To meet these goals, spaceflight missions have to manage

・forward contamination, contamination of celestial bodies other than the Earth by terrestrial life forms in the course of spaceflight missions (See Section 3.1.21), and

・backward contamination, contamination of the terrestrial biosphere by extraterrestrial life forms in the course of spaceflight missions (See Section 3.1.22).

Today COSPAR maintains and promulgates a planetary protection policy for the reference of spacefaring nations, both as an international standard on procedures to avoid organic constituent and biological contamination in space exploration, and to provide accepted guidelines and requirements in this area to guide compliance with the wording of the Outer Space Treaty.
In Japan, deep space exploration projects, mainly scientific satellites, have been conducted by adopting design standards that conform to the Planetary Protection Policy stipulated by COSPAR for individual projects, and by forming an international consensus at the COSPAR Planetary Protection Panel. In the past, individual projects have been implemented by adopting design standards that conform to the Planetary Protection Policy stipulated by COSPAR and by forming

an international agreement at the COSPAR Planetary Protection Panel. However, since there is a possibility that Japan will implement multiple projects that require planetary protection design, such as the Mars Sample Return (MMX), lunar exploration, and Mars exploration, JAXA will establish the Planetary Protection Program Standard as a JAXA standard, with the aim of centralizing the review process for planetary protection for JAXA as a whole. The purpose of this standard is to unify the review process for planetary protection in JAXA as a whole.

### 1.2 Scope of Application

This standard describes JAXA's planetary protection requirements. The contents are as follows

- The overall planetary protection management requirements (Chapter 4);
- The technical planetary protection requirements for robotic and human missions (forward and backward contamination) (Sections 5.1 – 5.3);
- The planetary protection requirements related to procedures (Sections 5.4);

The Document Requirement Descriptions (DRD) and their relation to the respective reviews (Sections 5.5 – 5.7).

This standard applies to

- Spaceflight missions conducted by JAXA:
- JAXA's participation in spaceflight missions conducted by JAXA:

JAXA's participation in spaceflight missions conducted by organizations other than JAXA. Participation here refers to the provision and operation of spacecraft, provision and operation of observation equipment, provision of elemental components, and provision of services (launch services, communication services, and relay functions, etc.) for the main spaceflight mission. For example, when a spacecraft or observation equipment provided by an organization other than JAXA is installed in a spaceflight mission conducted by JAXA, the spacecraft or observation equipment is subject to this standard.

The standard also applies to the provision of JAXA's launch services and communication services to spaceflight missions conducted by organizations other than JAXA, and JAXA may not provide services to spaceflight missions that do not conform to this standard. In the case of JAXA's participation in spaceflight missions conducted by organizations other than JAXA, priority shall be given to compliance with the planetary protection regulations established by organizations other than JAXA, and the method of implementing planetary protection shall be determined through consultation between JAXA and the other organization.

Spaceflight missions that do not reach Earth orbit or spaceflight missions that only target Earth orbit are, in principle, excluded from the scope because the probability of the flight instruments reaching solar-system celestial bodies including the Moon is extremely small. However, if there is a concern that the possibility of the flight instruments reaching solar-system celestial bodies

including the Moon beyond Earth orbit cannot be eliminated due to the large propulsion system capability of the launch vehicle or spacecraft, the Planetary Protection Officer or a person designated by the Planetary Protection Officer shall conduct an individual interview with the person in charge of the project to determine whether the flight instruments can reach solar-system celestial bodies including the Moon. The Planetary Protection Officer or a person designated by the Planetary Protection Officer shall conduct a hearing with the person in charge of the project individually and provide advice on the applicability of this standard.

The requirements described in this standard should be organized into those that apply to individual projects and those that do not, and tailored so that general and mission-specific requirements are retained and those that are unnecessary are omitted. (See the Mission Category Flowchart in Annex J for details on the scope of application.

## 2 RELATED DOCUMENTS

### 2.1 Applicable documents

The following documents form part of this Standard within the scope specified in this Standard, and unless otherwise specified, are the latest versions available at the time of application of this Standard. If there is any discrepancy between this Standard and the documents listed below, the discrepancy shall be reported to the Director of the Safety and Reliability Division and appropriate action shall be taken.

(1) JMR-005 Quality Assurance Program Standard
(2) JMR-006 Configuration Management Standard
(3) JMR-013 Quality Assurance Program Standard (Basic Requirements JIS Q 9100)

### 2.2 Reference Documents

2.2 Reference Documents

The following documents are provided as references to supplement the descriptions in this standard. Document (2) is a reference for evaluating the assembly environment and outgassing of flight equipment. Document (3) is a handbook that provides specific examples of crash probability analysis and contamination probability analysis described in this standard, and Documents (9)-(11) are references for performing such analyses. Documents (4) through (8) are references for sterilization (Section 3.1.15) and bioburden control (Section 3.1.2). Document (12) is the ESA standard document referred to in preparing this standard.

(1) JMR-001 System Safety Standard
(2) JMR-010 Contamination Control Standard

(3) JERG-0-057-HB001 Handbook for Probability of Impact Analysis for Planetary Protection
(4) JERG-0-057-HB002 Sterilization Handbook for Flight Instruments (in preparation for publication)
(5) JERG-0-057-HB003 Sterilization Handbook for Clean Rooms (in preparation for publication)
(6) JERG-0-057-HB004 Microbiological Inspection Handbook for Flight Instruments and Cleanrooms (in preparation for publication)
(7) JERG-0-057-HB005 Compatibility Testing Handbook for Materials and Components for Sterilization Processes (in preparation for publication)
(8) JERG-0-057-HB006 Handbook for Ultra-Cleaning of Flight Instruments (in preparation for publication)
(9) JERG-2-000 Spacecraft (Satellite and Spacecraft) Design Standard
(10) JERG-2-120 Single Failure and Ripple Failure Prevention Design Standard
(11) JERG-2-151 Mission and Orbit Design Standard
(12) ESSB-ST-U-001 Issue 1 Rev0 ESA planetary protection requirements

## 3 DEFINITION OF TERMS

### 3.1 Terms

3.1.1 assay

Collection and analysis of biological contamination with a specified procedure

3.1.2 bioburden

Number of microorganisms in the sample. The degree of biocontamination. or bioburden test (a test to test the degree of biocontamination), and the numerical value of the bioburden test result.

3.1.3 encapsulated bioburden

Bioburden encapsulated in non-metallic material (e.g., potting, FRP, etc.)

3.1.4 JAXA services

Launch services, communication services and relay functions provided by JAXA

3.1.5 exposed surfaces

Internal and external surfaces free for gas exchange

3.1.6 extant life

Form of life, or signatures thereof, whether metabolically active or dormant

3.1.7 extinct life

Form of life, or signatures thereof, that is unambiguously no longer metabolically active or dormant

3.1.8 inbound leg

In the frame of Earth-return missions (See section 3.1.20), part of the mission returning to Earth

3.1.9 mated surface

Surfaces joined by fasteners rather than by adhesives

3.1.10 outbound leg

In the frame of Earth-return missions (See section 3.1.20), part of the mission leaving Earth

Note: Used as an antonym for inbound leg and includes all activities on the way to and around the object

3.1.11 planetary protection category

Category of planetary protection assigned in consideration of the scientific importance of a target object with respect to chemical evolutionary processes and the origin of life, and the significance of contamination of the target object that could adversely affect future research. The categories vary according to the target object and mission type, and different requirements are set for each category.

3.1.12 protected Solar system body

(In the frame of impact probability analysis) Solar system bodies, including planets and moons, for which there is significant scientific interest relative to the process of chemical evolution and the origins of life and for which scientific opinion provides a significant chance that contamination by a spacecraft can compromise future investigations.

Note: In accordance with this definition and the categories defined in 4.2, protected Solar system bodies are assigned to planetary protection category III and IV.

3.1.13 restricted earth return

Planetary protection sub-category V for Earth-return missions (See section 3.1.20) from Solar system bodies deemed by scientific opinion to have a chance of harbouring indigenous life forms

3.1.14 single landing event

Pre-launch prediction of the individual spacecraft system landing/impact locations that cannot be demonstrated to be outside each other’s 3σ level.

Note: For example, if a lander separates the aeroshell and lands, the landing of the lander and the fall of the aeroshell are treated as a single landing event if the center of the dispersion region of the predicted landing site of the lander is included in the 3σ dispersion region of the predicted fall of the aeroshell.

3.1.15 sterilization

In this standard, methods and processes that have been approved as effective for eliminating viable microorganisms from products

3.1.16 unrestricted earth return

Planetary protection sub-category V for Earth-return missions (See section 3.1.20) from Solar system bodies deemed by scientific opinion to have no indigenous life forms

3.1.17 launch vehicle

Systems for transporting spacecraft, such as rockets, out of the Earth's gravitational sphere

3.1.18 flight hardware

All instruments to be transported outside the Earth's gravity zone, including launch vehicles and spacecraft.

3.1.19 noncompliance

A condition of an item or facility in which one or more of its characteristics do not match the requirements or are abnormal and cannot be made to satisfy the requirements by repair or other means. A waiver application should be filed.

3.1.20 Earth-return mission

All missions in which a spacecraft, a part of a spacecraft, or a sample of a spacecraft affected by solar system bodies other than the Earth and the Moon return to and affect the Earth's atmosphere (including the Moon). All missions in which a spacecraft, part of a spacecraft, or a sample of a spacecraft affected by the Moon returns to the Earth and has an affected impact. Here, "affected" refers to any event that cannot exclude the possibility of material transport from the target object to the spacecraft, including landing, atmospheric entry, and flyby, and "influenced" refers to any event that cannot exclude the possibility of material transport from the spacecraft to the target object, including landing, atmospheric entry, and flyby. Whether the spacecraft was affected by the target object or affected by the target object shall be determined on a case-by-case basis based on scientific knowledge.

3.1.21 forward contamination

Contamination of celestial bodies other than the Earth by terrestrial life forms in the course of spaceflight missions

3.1.22 backward contamination,

Contamination of the terrestrial biosphere by extraterrestrial life forms in the course of spaceflight

missions

3.1.23 Mars special region

Area or volume within which sufficient water activity AND sufficiently warm temperatures to permit the replication of Earth organisms

a) The physical parameters that specify the Mars special region are:

1. Lower limit for water activity: 0.5; upper limit: 1.0.
2. Lower limit for temperature: -28 °C; no upper limit defined.
3. Timescale within which limits can be identified: 500 years.

b) Areas where the following features are observed will be treated as Mars special regions until proven to be exempt

1. Gullies (Classification Nos. 2-4), and bright streaks associated with gullies (Reference [7])
2. Underground cavities
3. Deeper than 5m underground
4. Confirmed or partially confirmed Recurrent Slope Lineae (RSL). Observational evidence of RSL, taken from reference [8], are:
   - Confirmed: Simultaneous growth and decay of flows on warmer slopes observed, with this sequence repeated in multiple Martian years.
   - Partially confirmed: growth or recurrence observed.
   - Candidate: Streak patterns on slopes that resemble RSLs but currently lack the observations necessary for partial confirmation.

c) If any of the following features are discovered in the future, treat the area as a Mars Special Area until proven inapplicable.

1. Groundwater
2. Methane sources
3. Geothermal activity
4. Traces of recent spills

d) Areas where the following features are observed should be evaluated individually before being classified as Mars Special Regions.

1. Dark striations
2. Paste-like landforms
3. Candidates for RSL (Section 3.1.23 b) b) 3)

Note: In the absence of specific information, no special regions are currently identified on the basis of possible Martian life forms.

Note: Special areas induced by spacecraft are determined individually based on the above conditions and characteristics.

3.1.24 D-value

Time or dose required to achieve inactivation of 90 % of a population of the test microorganisms under stated conditions.

3.1.25 life detection investigation

Scientific investigations that can detect signatures of extant life.

3.1.26 Permanently Shadowed Regions; PSRs

An area permanently out of direct sunlight on the Moon.

**3.2 Abbreviation**

| | |
|---|---|
| COSPAR | Committee on Space Research |
| CDR | Critical Design Review |
| DRD | Document Requirement Descriptions |
| ISO | International Organization for Standardization |
| LRR | Launch Readiness Review |
| MDR | Mission Definition Review |
| NAC | NASA Advisory Council |
| PDR | Preliminary Design Review |
| PPOSS | Planetary Protection of Outer Solar System |
| PPO | Planetary Protection Officer |
| PPS | Planetary Protection Subcommittee |
| PSR | Pre-Ship Review |
| SDR | System Definition Review |
| SRR | System Requirements Review |
| VTL | Verification Tracking Log |

# 4 MANAGEMENT REQUEST

## 4.1 Planetary protection roles and responsibilities

### 4.1.1 Corporate level

JAXA is responsible for overseeing the correct implementation of our Planetary Protection Policy under the Safety Review Board. The Chairperson of the Safety Review Board shall appoint the Planetary Protection Review Board and its Chairperson. The Senior Chief Officer of the Safety and Mission Assurance Department shall appoint the Planetary Protection Officer (PPO) with the Chairperson of the Planetary Protection Review Board. The Planetary Protection Review Panel shall consist of experts within and outside JAXA who are involved in planetary protection. The Planetary Protection Officer (PPO) is responsible to:

- Establish and maintain standards for planetary protection, including the JAXA Planetary Protection Program Standard (this Standard):
- Act as JAXA's point of contact for matters of planetary protection with other Agencies and International Organizations;
- Act as JAXA's representative at COSPAR for planetary protection issues, including reporting to COSPAR on the planetary protection compliance of JAXA' s spaceflight missions;

Advise and support relevant JAXA's programs and projects on matters of planetary protection.

In addition, the Planetary Protection Officer, as the Chairperson of the Planetary Protection Review Board, is responsible to:

- Approve planetary protection categorization and requirements for flight projects.
- Conduct inspections and reviews of facilities, equipment, procedures, and practices in coordination with ongoing projects to assess their adequacy for compliance with planetary protection requirements and make corrective recommendations as necessary.

Review planetary protection compliance during the spaceflight mission, prior to launch, prior to transition to the return phase of the mission if the spacecraft is returning, prior to atmospheric re-entry, and prior to unpacking the returned samples.

### 4.1.2 Project level

The Project Manager (PM) is responsible for the correct identification and implementation of planetary protection requirements at the project level. The Project Manager designates a Planetary Protection Manager (PPM) (who may also be the PM). The Planetary Protection Manager is responsible to:

- Identify the planetary protection requirements specific to the project by tailoring this standard and relevant planetary protection standards in in JAXA approved design standards.

- Define the planetary protection implementation and management approach.
- Define the planetary protection implementation structure within the project.
- Develop project-level planetary protection documentation.
- Consider implementation of the recommendations in the review regarding planetary protection.

### 4.2 Planetary protection category definitions

The different planetary protection categories reflect the level of interest and concern that contamination can compromise future investigations. The categories and associated requirements depend on the target body and mission type combinations. In some missions, more than one category may be selected.

The following description is based on the COSPAR classification at the time of issuing this document. The latest and/or applicable classification and associated requirements are provided, for each particular case, by the Planetary Protection Officer.

The mission category flowchart in Annex J can be used to determine which planetary protection category each mission fits into.

#### 4.2.1 Category I

See Annex K.1 for an example of Category I task.

Description

All types of missions to a target body for which there is no significant scientific interest relative to the process of chemical evolution and the origins of life.

Applicability

S-type asteroids, Io, Mercury.

Requirements

None.

#### 4.2.2 Category II

See Annex K.1 for an example of Category II task.

Description

All types of missions to a target body for which there is significant scientific interest relative to the process of chemical evolution and the origins of life but for which scientific opinion provides only a remote chance that contamination by a spacecraft can compromise future investigations.

Applicability 1

Venus, Comets, P, D, and C-type asteroids, Jupiter, Jovian moons (except Io, Europa, and Ganymede), Saturn, Saturnian moons (except Titan and Enceladus), Uranus, Uranian moons, Neptune, Neptunian moons (except Triton), Kuiper Belt Objects less than 1/2 the size of Pluto

Applicability 2

Moon (Classified as Cat. II, IIa, or IIb. see Section 5.3.1)

Applicability 3

Ganymede, Titan, Triton, Pluto, Charon, Kuiper Belt objects larger than 1/2 the size of Pluto.

Requirements

Simplified documentation tailoring the planetary protection documentation requirements. For Applicability 2 (Moon), an organic materials inventory may be required (see Section 5.3.1). Applicability 3 may be classified as Category II if there is less than a $1x10^{-4}$ chance that the liquid water environment that may exist beneath the surface of the target object will be contaminated (i.e., reach even one organism capable of propagating on Earth) during the mission in question. In this case, both the presence of such an environment and the likelihood of contact should be analyzed.

### 4.2.3 Category III

See Annex K.2 for an example of Category III task.

Description

Flyby and orbital missions to protected Solar System bodies (see section 3.1.12).

Applicability

Mars, Europa, Enceladus.

Requirements

Detailed documentation in accordance with the Planetary Protection Documentation Requirements. Organic materials inventory, Impact probability analysis, and Contamination probability analysis.

### 4.2.4 Category IV

Description

Surface to protected Solar System bodies (see section 3.1.12).

Applicability

Mars, Europa, Enceladus.

Requirements

Detailed documentation in accordance with the Planetary Protection Documentation Requirements. Organic materials inventory. Storage of organic samples. Bioburden control and sterilization of materials, parts, assemblies, and equipment.

### 4.2.5 Category V

Description

All Earth-return missions (see section 3.1.20). For Solar system bodies deemed by scientific opinion to have no indigenous life forms, a subcategory a) “unrestricted Earth return” (see section 3.1.16) is defined. For all other Category V missions, a subcategory b) “restricted Earth return” (see section 3.1.13) is defined.

Applicability

a) Unrestricted Earth return

Venus, Moon, B-, C-, and S-type asteroids, Io, Mercury, etc. However, in principle, the decision on these asteroids will be determined on a case-by-case basis.

b) Restricted Earth return

Mars, Europa, Enceladus. However, in principle, this will be determined on a case-by-case basis.

Requirements

a) Unrestricted Earth return

Corresponding to the category of the outbound phase (typically Category I or II), it has only the planetary protection requirements for this phase.

b) Restricted Earth return

- Containment shall be performed during the entire return phase for all spacecraft, parts of spacecraft, or samples that have been affected by the target object and that have not been sterilized. The term “returning” here refers to leaving the target celestial body and returning to the Earth’s biosphere (including the Moon) and being on an impact trajectory (see Section 3.1.20). And “containment” means that the following microbiological contamination probability requirements are satisfied:

  The probability of leakage of a single unsterilized particle larger than 10 nm to the outside

world during the first 100 years after departure of the target object shall be less than $10^{-6}$ (Reference [9]).

Note 1: The rationale for the microbial contamination probability requirement is to “break the chain of contact” between the protected solar-system bodies and the Earth’s atmosphere.

Note 2: See Reference [10] for the rationale for this value.

Note 3: The term “particle” as it appears in the above requirement includes material from the target object, as well as spacecraft and parts of spacecraft affected by the target object.

Note 4: The minimum size of 10 nm shall tentatively follow the ESA standard at this time, but shall be discussed and re-established based on the latest scientific knowledge, if necessary, when a case arises in the future in which this provision is applied.

- Conducting timely analyses of any unsterilized sample collected and returned to Earth, under strict containment, and using the most sensitive techniques. If any sign of the existence of a non- terrestrial replicating entity is found, containment of the returned sample, unless treated by an effective sterilizing procedure. Here, “strict containment” means that the probability of leakage of a single unsterilized particle larger than 10 nm to the outside world during the first 100 years after departure of the object is less than $10^{-6}$ (see “Microbial Contamination Probability Requirement” in the previous section).

The requirement for the outbound phase is generally Category IV.

Note: The Earth’s Moon is considered to be part of the Earth-Moon system, and the same level of protection from backward contamination is provided to the Moon as to the Earth.

For Category V missions, changes in circumstances that occur during the mission period may result in a category change or mission failure.

In these cases, the sample that was to be brought back shall be abandoned and, if already collected, the spacecraft carrying the sample shall not be allowed to return to and impact the Earth’s biosphere (including the Moon) (see Section 3.1.20). Such examples include the following:

- When new data or scientific findings change the category from unconstrained Earth return (see Section 3.1.16) to constrained Earth return (see Section 3.1.13) and safe return of the sample cannot be guaranteed
- In the case of a constrained Earth return (see section 3.1.13) mission, the sample containment environment is no longer reliable, and sterilization of the sample is not possible.

# 5 TECHNICAL REQUIREMENTS

## 5.1 General requirements for all missions

a) The head of the working group proposing a JAXA project shall develop a preliminary project planetary protection requirement document in compliance with the DRD in Annex A as part of the draft mission requirement document for review by the Chairperson of Planetary Protection Review Board during the Mission Definition Phase, by the Mission Definition Review (MDR).

Note 1: In the ESA standard, only described as the project manager, but in the JAXA Project Management Implementation Guideline, the project manager is the head of the working group in the above phase.

Note 2: The ESA standard requires that the project planetary protection requirements be prepared by the Preliminary Requirements Review (PRR), but the JAXA Project Management Implementation Guideline does not specify a PRR, and the MDR or the Project Readiness Review shall take the place of the PRR. Therefore, a preliminary project planetary protection requirements document shall be prepared by the MDR.

b) For missions that target or encounter multiple Solar system bodies, all applicable planetary protection requirements for all relevant protected Solar system bodies (see section 3.1.12) shall be described in the preliminary project planetary protection requirements document.

c) The Chairperson of Planetary Protection Review Board shall review compliance with the requirements in the Preliminary Project Planetary Protection Requirements Document, based on this Standard, the COSPAR Planetary Protection Policy and Requirements, and any planetary protection-related obligations requested by the relevant external planetary protection authorities.

d) The preliminary project planetary protection requirements approved by the Chairperson of Planetary Protection Review Board and authorized by the head of the working group proposing the project shall be baselined as part of the mission requirements document and released by the System Requirements Review (SRR) at the latest.

e) The Planetary Protection Officer, in cooperation with the head of the working group proposing the project, shall report to the COSPAR Planetary Protection Panel on the planetary protection categories to be established and the planetary protection plan as early in the project phase as possible (preferably before the preliminary design review) to build international consensus.

Note 1: Since the COSPAR Planetary Protection Panel will be held every other year, there is a risk that consensus building in COSPAR will not be consistent with the project schedule. If the planetary protection category is changed after the project has made considerable progress due to lack of international consensus, it will not only be a major setback, but also make it difficult to continue the project in some cases. To avoid such risks, it is recommended that the Planetary Protection Officer, in cooperation with the head of the working group proposing the project, coordinate with the COSPAR Planetary Protection Panel as early in the project as

possible.

f) JAXA flight hardware and JAXA services delivered to non-JAXA mission subject to planetary protection constraints shall be reviewed in principle in accordance with the documentation requirements in section 5.5 and the review requirements in section 5.6 to ensure that they satisfy JAXA's planetary protection requirements.
Note: The mission lead of the non-JAXA mission bears the overall planetary protection responsibility at mission level, including assigning, monitoring, reviewing and approving planetary protection categories and associated requirements.

g) If a significant change in the mission baseline occurs, the Project Manager shall evaluate the impact of this change on the planetary protection requirements and planetary protection implementation methods, propose countermeasures, and obtain approval from the Planetary Protection Review Board Chairperson. If the Planetary Protection Review Board Chairperson determines that there will be a significant change in the planetary protection requirements and planetary protection practices, the Planetary Protection Review Board and the Safety Review Board shall review the adequacy of the countermeasures.

## 5.2 Generic technical requirements

### 5.2.1 Material management of flight hardware assembly and manufacturing parts, etc.

a) Except as specified in paragraph 5.2.3 b), all flight hardware subject to planetary protection constraints shall be assembled and maintained in a permanently operating ISO Class 8 clean room or better air cleanliness-controlled environment at all times as specified in the Contamination Control Standard (JMR-010).

b) Except as specified in 5.2.3 b), all flight hardware subject to planetary protection constraints shall be properly cleaned as specified in the Contamination Control Standard (JMR-010) for materials such as manufactured parts processed in an environment less clean than that of a permanently operating ISO Class 8 clean room.
Note: The clean room in storage is in operation, and the cleanliness of the air must be equal to or better than that of an ISO Class 8 clean room in continuous operation.

### 5.2.2 Right of access

a) Chairperson of the Planet Protection Review Division or designee shall conduct independent verification assays on flight hardware and controlled environments, including launch site, during the course of the project at times and intervals planned and agreed with the Project Manager.
Note: This requirement applies to projects where cleanliness control is a concern or where bioburden control is required.

### 5.2.3 Impact probability on a protected Solar system body

a) For missions that target or have the potential to encounter protected solar system bodies (see section 3.1.12), the following probability of impact requirements shall be satisfied for all relevant protected solar system bodies. It shall also be verified by an impact probability analysis.

b) For any configurations of the spacecraft that is not assembled or maintained under controlled conditions in a permanently operating ISO Class 8 clean room or cleaner air, the probability of impact on a protected solar system object shall be less than $1x10^{-4}$ over the first 50 years after launch.

Note: Examples of these configurations are the upper stage of the launch vehicle, the kick motor, and other parts that are transported outside the Earth' s gravity sphere.

c) One of the following conditions shall be satisfied:

1. For any component of a spacecraft assembled and maintained under controlled conditions in a permanently operating ISO Class 8 clean room or cleaner air, the probability of impact with a protected solar system object shall be less than $1x10^{-2}$ for the first 20 years after launch. Also, the probability of impact with a solar system object shall be less than $5x10^{-2}$ for a period of 20 to 50 years after launch.

2. The entire spacecraft, including surfaces, bonded surfaces, and encased objects, shall have a bioburden of $5x10^{5}$ spores or less.

Note: This requirement also applies to flybys and gravity-assisted maneuvers to protected Solar System bodies.

d) Impact probability analysis as specified in clause 5.2.3 a) shall include the following:

1. Single/multiple pass analysis;
2. Spacecraft reliability;
3. Meteoroid impacts;
4. Knowledge of spacecraft state (location, velocity vector);
5. Maneuver and planet/moon ephemeris uncertainty;
6. Stochastic variability of the atmospheric density with the amplitude of the Solar cycle estimated for the mission/sun epoch as variable.

### 5.2.4 Contamination probability on a protected Solar system body

a) For missions that target or may encounter protected solar system bodies (see Section 3.1.12), all relevant protected Solar System bodies shall have a contamination probability by Earth-derived viable microorganisms of less than $1x10^{-3}$ or less for 50 years after arrival at the target object, except as otherwise required by this Standard.

### 5.2.5 Organic materials inventory

If the spaceflight mission corresponds to the following, the DRD in Annex H shall be complied with and an organic materials inventory shall be developed based on the individual mission requirements (see Section 5.3).

a) Be one of the following:
   1. Moon landing mission (see section 5.3.1).
   2. Missions classified as Category III or Category IV. However, an organic materials inventory is not required for spacecraft or spacecraft elements (e.g., the orbiter portion of a combined orbiter and lander) that meet the Probability of Impact requirements for protected Solar System Objects (see Section 3.1.12) in Section 5.2.3b) and c)1.
b) If the total amount of the total accumulated items used on the spacecraft exceeds the upper limit (normally 1 kg) agreed upon with the Chairperson of the Planetary Protection Review Board.

Unless specifically exempted, the organic materials inventory shall list all items used on the spacecraft that have a total integrated weight greater than 1 kg. The organic materials inventory shall include organic products that spacecraft with propulsion and life support systems may release into the moon's surface and the environment of the Solar System bodies to be protected, including a quantitative and qualitative description of the major chemical constituents, and integrated quantities of trace chemical constituents present.

## 5.3 Requirements for specific missions

### 5.3.1 Requirements for Moon missions

5.3.1.1 Moon orbit and fly-by mission

Moon orbit and fly-by missions are classified as Category II, to which the general requirements in Section 5.1, the technical requirements in Section 5.2, the documentation requirements in Section 5.5, the requirements for reviews in Section 5.6, and Section 5.7 shall be applied. However, it is not necessary to submit an Organic materials inventory (Annex H).

5.3.1.2 Moon Landing Missions

Moon landing missions are classified as Category IIa or IIb. All those that are not in Category IIb are in IIa. For Category IIa Moon landing missions, in addition to the requirements of Section 5.3.1.1, an organic materials inventory shall be submitted for organic products that may be released into the Moon's environment by the propulsion system, in conformance with DRD on Section H.2.1 in Annex H.

5.3.1.3 Surface missions to Permanently Shadowed Regions (PSR) and polar regions

Moon landing missions that reach the Permanent Shadow Region (PSR) or the polar regions (especially south of 79°S latitude and north of 86°N latitude) in nominal operations are classified as Category IIb. For these missions, the DRD in Annex H shall be complied with and an Organic materials inventory shall be submitted for any organic material whose total amount on the spacecraft, exceeds the upper limit (normally 1 kg) agreed with the Chairperson of the Planetary Protection Review Board.

Note: For Moon missions, it is common practice to tailor the document requirements and provide a "Planetary Protection Plan" that integrates the Project Planetary Protection Requirements, Planetary Protection Plan, and Planetary Protection Implementation Plan into a single document, which is subject to planetary protection review before the CDR.

### 5.3.2 Requirements for Mars missions

5.3.2.1 General requirements for Mars missions

a) An organic materials inventory in conformance with Section 5.2.5 shall be provided by the project. However, an organic materials inventory is not required for a spacecraft or spacecraft element (e.g., orbiter element of an orbiter-lander spacecraft stack) meeting the probability of impact requirement for Mars described in Sections 5.2.3b) and c)1.

b) For all organic materials used as elements of a spacecraft weighing 25 kg or more, a 50 g sample of each shall be stored for 50 years after launch in a clean room of ISO Class 8 under operation, or under controlled conditions with air cleanliness better than that of a clean room. However, for a spacecraft or spacecraft element (e.g., orbiter element of an orbiter-lander spacecraft stack) meeting the probability of impact requirement for Mars described in 5.2.3b) and c)1, organic materials inventory is not required.
   Note: Samples can be either at the raw material level or at the product's material level.

c) All bioburden constraints shall be verified pre-launch.
   Note: This verification is usually performed on final physical access to the flight hardware or flight hardware elements, *i.e.*, at delivery of flight hardware to next level contractor, delivery to launch site, and at the launch site prior to fairing closure.

d) In this standard, all bioburden constraints shall be defined based on the number of aerobic microorganisms (hereafter referred to as spores) that can withstand a heat shock of 15 minutes at 80°C and have been incubated for 72 hours at 32°C on TSA (Tryptic Case Soy Agar).

5.3.2.2 Requirements for Mars surface missions

5.3.2.2.1 Overview

Mars surface missions are classified as among Categories IVa, IVb, and IVc. All missions that are not in categories IVb and IVc are IVa. Requirements in 5.3.2.2.2 are applicable to all Mars surface missions. Additional requirements apply depending on the mission objective (5.3.2.2.3) and

location on Mars (5.3.2.2.4)

5.3.2.2.2 General requirements

a) The bioburden of the landed system shall be ≤ $3x10^5$ bacterial spores on exposed internal and external surfaces.

b) The average bioburden of the landed system shall be ≤ 300 spores/$m^2$ on exposed internal and external surfaces.

The project shall provide an analysis whether the spacecraft in nominal and off-nominal conditions has the potential to locally alter the Martian environment in a way that can create a Mars special region as defined in Section 3.1.23.

Note: Such an analysis is especially important for spacecrafts using radioisotope heat sources targeting areas with surface or sub-surface water ice.

5.3.2.2.3 Requirements for surface missions with life detection

Surface missions with life detection s are defined as Planetary Protection Category IVb.

a) One of the following conditions shall be met:

1. The bioburden of the entire surface system shall be ≤ 30 bacterial spores on exposed internal and external surfaces, or at or below a contamination level driven by the nature and sensitivity of the particular life detection investigation.
2. The average bioburden of the subsystems that are involved in the acquisition, delivery, and analysis of samples used for life-detection investigations is either:
   (a) a spore density ≤ 0.03 bacterial spores/$m^2$, or
   (b) at or below a contamination level driven by the nature and sensitivity of the particular life-detection investigation. In addition, recontamination prevention of these subsystems and the samples to be analyzed is in place until the end of the life-detection investigations.

5.3.2.2.4 Requirements for surface missions accessing Mars special regions

Surface missions accessing Mars special regions are defined as Planetary Protection Category IVc.

a) If the landing site is within a Mars special region as defined in 3.1.23, the bioburden of the entire surface system shall be ≤ 30 bacterial spores on exposed internal and external surfaces.

b) If a Mars special region as defined in 3.1.23 is accessed through horizontal or vertical mobility, one of the following conditions shall be met:

1. The bioburden of the entire surface system is ≤ 30 bacterial spores on exposed internal and

external surfaces.

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

NOTE Example of accessing Mars special regions are by roving (horizontal mobility) or flying (horizontal mobility) or by drilling (vertical mobility).

NOTE Item 1 for a case with the entire surface system accessing, and item 2 for a case with the subsystems only accessing.

c) If an off-nominal condition can cause a high probability of inadvertent biological contamination of a Mars special region by the spacecraft, the bioburden of the entire surface system shall be ≤ 30 bacterial spores on exposed internal and external surfaces, and the total mated and encapsulated bioburden level shall be ≤ $2.0 \times 10^5$ bacterial spores.

Note: Example for off-nominal condition is a hard landing.

Note: This bioburden level takes into account robust microbial outbreaks against sterilization methods. This specification assumes that the surface cleanliness reaches Category IVa and that the number of viable bacteria is reduced by at least four orders of magnitude afterwards. The validation of the bioburden level is based on a pre-sterilization assessment of the bioburden and knowledge of the reduction rate due to the sterilization methods.

5.3.2.3 Requirements for Mars sample return missions

a) Mars sample return missions are classified as Category V “Constrained Earth Return (see Section 3.1.13”. Unless specifically exempted, the Category IVb requirements specified in section 5.3.2.2.3 shall be applied to the outbound leg of a Mars sample return mission.

Note: This provision is intended to avoid “false positive” in life detection and hazard determination procedures, or in the search for life in samples after their return. “False positives” could prevent the distribution of samples from under containment and lead to unnecessarily stringent requirements for all subsequent Mars missions.

b) Unless the samples to be returned from Mars are subjected to an approved sterilization process, the canisters containing the samples returned from Mars shall be sealed by an appropriate verification process and the samples shall remain contained during all mission phases through transport to a receiving facility where they can be opened under containment.

c) The mission and spacecraft design shall provide a method to “break the chain of contact” with Mars. No uncontained hardware that contacted Mars, directly or indirectly, shall be returned to the Earth’s biosphere or the Moon. Isolation of such hardware from the Martian environment shall be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.

d) In order to continue the mission, the mission must be reviewed by the Planetary Protection Review Board and approved by the Safety Review Board at the following three stages:

1. prior to launch from Earth
2. prior to leaving Mars for return to the Earth's atmosphere
3. prior to commitment to Earth re-entry (must be avoidable)

e) 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 prerequisite for the controlled distribution of any portion of the sample. No distribution shall be made until the results have been reviewed by the Planetary Protection Review Board and approved by the Safety Review Board.
Note: As a result of the above, the probability of leakage of single unsterilized 10 nm or larger particle into the Earth biosphere (including the Moon) during the first 100 years after departure from Mars must be ≤ $10^{-6}$ (see Section 4.2.5, requirement b),"Microbial contamination probability requirement").

f) Materials returning from Mars, including spacecraft surfaces exposed to the Martian environment, shall be treated as Hazard Level I (catastrophic) as specified in the System Safety Standard (JMR-001) until the hazard level is identified.

5.3.2.4 Guidelines for human Mars missions

No specific requirements have yet been established for manned Mars missions. General implementation guidelines for human Mars missions for planetary protection are described in Annex I.

### 5.3.3 Requirements for missions to Europa, Enceladus, and other Solar system bodies in the outer Solar system

5.3.3.1 Applicability for Solar system bodies in the outer Solar System

a) Missions to Europa, Enceladus, Ganymede, Titan, Triton, Pluto, Charon, and Kuiper Belt Objects bigger than ½ size of Pluto, shall comply with requirements in Section 5.3.3.
Note: The Planetary Protection Officer can provide the most recent and applicable set of requirements.

5.3.3.2 General requirements

a) The period of biological exploration for Europa and Enceladus is defined to be 1,000 years. This period should start at the beginning of the 2$^{1s}$t century. Requirements for Europa and Enceladus fly-bys, orbiters, and landers (including bioburden reduction) shall be applied to reduce the probability of inadvertent contamination of Europan and Enceladan subsurface liquid water to less than 1x$10^{-4}$ per mission. The 1x$10^{-4}$ probability of inadvertent contamination of a Europan or Enceladan oceans shall apply to all mission phases, including the duration that spacecraft introduced Earth-derived life may remain viable and could reach a sub-surface liquid water environment.

b) In calculating the probability of inadvertent contamination as specified in 5.3.3.2 a), at minimum the following factors shall be taken into account and a conservative estimate shall be adopted for any poorly known parameters.
   1. Total amount of bioburden at launch
   2. Probability of bioburden reduction during interplanetary flight (survival probability of remaining life forms on the spacecraft)
   3. Probability of bioburden reduction in each radiation environment
   4. Probability of spacecraft landing on the surface of a celestial body
   5. The mechanisms and time scales of transport to a sub-surface liquid water environment
   6. Probability of survival and proliferation of organism before, during, and after sub-surface transfer

c) Probability calculations of inadvertent contamination will likely result in requirement of bioburden reduction even for Europa and Enceladus orbiters (Category III) as well as for landers (Category IV). The use of clean room technology, the cleanliness of all components prior to assembly, and the monitoring of spacecraft assembly facilities will be required to conduct a bioburden and biodiversity assessments, including specific relevant organisms. Relevant organisms are terrestrial organisms potentially present on the spacecraft that can survive the spaceflight environment and the icy moon environment, and replicate in icy moons sub-surface liquid water. Specific methods should be developed to identify, enumerate, and eradicate problematic species.

5.3.3.3 Requirements for Europa・Enceladus sample return mission

a) Europa・Enceladus sample return missions are classified as Category V “restricted earth return (see Section 3.1.13)”. Unless specifically exempted, the Category IVb requirements specified in Section 5.3.2.2.3 shall be applied to the outbound leg of the Europa and Enceladus sample return mission.
   Note: This provision is intended to avoid “false positive” in a life detection and hazard-determination protocol, or in the search for life in the samples after their return. The “false positive” could prevent distribution of the samples from under containment and lead to unnecessarily stringent requirements for all subsequent Europa and Enceladus missions.
b) Unless the samples to be returned from Europa (or Enceladus) are subjected to an approved sterilization process, the canister containing the samples returned from Europa (or Enceladus) shall be sealed with an appropriate verification process and the samples shall remain sealed at all mission stages through transport to a receiving facility where they can be opened under containment.
c) The mission and spacecraft design must provide a method to “break the chain of contact” with Europa (or Enceladus). No uncontained hardware that contacted material from Europa (or

Enceladus) or its plumes shall be returned to the Earth's biosphere (including the Moon). Such hardware must be isolated from the Europa (or Enceladus) environment during the sample container loading into the containment system, launch from Europa (or Enceladus), and any in-flight transfer operations required by the mission.

d) In order to continue the mission, the mission must be reviewed by the Planetary Protection Review Board and approved by the Safety Review Board at the following three stages:
   1. prior to launch from Earth
   2. prior to leaving Europa (or Enceladus) to Earth's biosphere
   3. prior to commitment to Earth re-entry (must be avoidable)

e) 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 prerequisite for the controlled distribution of any portion of the sample. No distribution shall be made until the results have been reviewed by the Planetary Protection Review Board and approved by the Safety Review Board.
   Note: As a result of the above, the probability of leakage of a single unsterilized 10 nm or larger particle into the Earth's biosphere (including the Moon) during the first 100 years after departure from Europa (or Enceladus) must be $\leq 10^{-6}$ (see Section 4.2.5, requirement b), "Microbial contamination probability requirement").

f) Materials returning from Europa (or Enceladus), including spacecraft surfaces exposed to the Europa (or Enceladus) environment, shall be treated as Hazard Level I (catastrophic) as specified in the System Safety Standard (JMR-001) until a hazard level is identified.

### 5.3.4. Requirements for missions to small Solar system bodies

5.3.4.1 General requirements

a) Categorization of missions to small Solar system bodies shall be evaluated on a case-by-case basis.
   Note: There are a great many small bodies in the Solar system that are not listed in this Standard. Most small body missions are classified as Category I or II for forward contamination and Category V "a) unrestricted earth return (see Section 3.1.16)" for backward contamination.
   Note: Planetary protection categories specified by the project shall be reviewed by the Planetary Protection Review Board, approved by the Safety Review Board, and then reported to the COSPAR Planetary Protection Panel to reach an international consensus on their validity.

b) For Planetary Protection Category V, if the answers to the following six questions are all "no" or "uncertain", the mission shall be classified as "b) restricted earth return (see Section 3.1.13)", otherwise (even one "yes") it shall be classified as "a) unrestricted earth return (see

Section 3.1.16)".

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

c) If a mission is categorized as “restricted earth return (see section 3.1.13)” in accordance with section 5.3.4.1b, containment procedures shall be applied to the mission as described in section 5.3.4.2.

5.3.4.2 Requirements for restricted earth return missions

a) Unless specifically exempted, the requirements of Category IVb specified in section 5.3.2.2.3 shall be applied to the outbound leg of a mission classified as restricted earth return (see section 3.1.13).
Note: This requirement is intended to avoid "false positives" in a life detection and hazard-determination protocol or in any search for life in the samples after their return. The "false positives" could prevent distribution of the samples from under containment and could lead to unnecessarily stringent requirements for all subsequent missions to similar bodies

b) Unless the samples to be returned from the target body are subjected to an approved sterilization process, the canisters containing the samples returned from the target body shall be sealed with an appropriate verification process and the samples shall remain contained during all mission phases through transport to a receiving facility where they can be opened under containment.

c) The mission and spacecraft design shall provide a method to "break the chain of contact" with the target celestial body. No uncontained hardware that contacted Mars, directly or indirectly,

shall be returned to the Earth’s biosphere or the Moon. Isolation of such hardware from the target environment shall be provided during sample container loading into the containment system, launch from the target, and any in-flight transfer operations required by the mission.

d) In order to continue the mission, the mission must be reviewed by the Planetary Protection Review Board and approved by the Safety Review Board at the following three stages:
   1. prior to launch from Earth
   2. prior to leaving the target body for return to Earth's biosphere
   3. prior to commitment to Earth re-entry (must be avoidable)

e) 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 prerequisite for the controlled distribution of any portion of the sample. No distribution shall be made until the results have been reviewed by the Planetary Protection Review Board and approved by the Safety Review Board.
   Note: As a result of the above, the probability of leakage of a single unsterilized 10 nm or larger particle into the Earth biosphere (including the Moon) during the first 100 years after departure from the target body must be $\leq 10^{-6}$ (see Section 4.2.5, requirement b), "Microbial contamination probability requirement").

f) Material returning from a target body, including spacecraft surfaces exposed to the target body environment, shall be treated as Hazard Level I (catastrophic) as specified in the System Safety Standard (JMR-001) until a hazard level is identified.

## 5.4 Requirements for planetary protection procedures

### 5.4.1 Bioburden controlled environment

For the bioburden control in the spacecraft development environment, the sterilization handbook for clean rooms (JERG-0-057-HB003) shall be applied.

### 5.4.2 Bioburden assessment

a) Bioburden assessment on flight hardware shall be performed, using procedures "Swab assay 1 (standard swab assay)" or "Wipe assay 1 (standard wipe assay) "described in Annex of Microbial Inspection Handbook for Flight Instruments and Clean Room (JERG-0-057-HB004).

b) If direct assays are not possible, estimation of the flight hardware bioburden using the worst value in the respective category of Table 5.4-1 shall be used.

**Table 5.4-1: Bioburden estimation**

| Bioburden type | Specific environment | Bioburden value |
|---|---|---|
| Average encapsulated (i.e. in the material) spores density | Non-metallic parts of the spacecraft | 130 spores/$cm^3$ |
| Source specific encapsulated spore density | Electronic piece parts | (3 – 150) spores/$cm^3$ |
| | Other non-metallic materials | (1 – 30) spores/$cm^3$ |
| Source specific enclosed surface spore density, e.g. a box closed in the specific environment | ISO class 8 cleanroom, highly controlled: | (500 – 5000) spores/$m^2$ |
| | ISO class 8 cleanroom, normally controlled: | (5000 - $10^5$) spores/$m^2$ |
| | Uncontrolled environment: | ($10^5$ - $10^6$) spores/$m^2$ |
| Average surface spore density for cleanroom classes “in operation” (exposed and mated but non-encapsulated) | ISO class 7 cleanroom or better, highly controlled: | 50 spores/$m^2$ |
| | ISO class 7 cleanroom or better, normally controlled: | 500 spores/$m^2$ |
| | ISO class 8 cleanroom, highly controlled: | 1000 spores/$m^2$ |
| | ISO class 8 cleanroom, normally controlled: | 10000 spores/$m^2$ |
| | Uncontrolled environment: | $10^5$ spores/$m^2$ |
| NOTE 1: Highly controlled: bioburden control with full-body coveralls, hoods, face masks, gloves, and boots installed, access control with appropriate access/exit protocols, and dedicated cleanliness controls (e.g., HEPA filters and dedicated cleaning).<br>NOTE 2: Normally controlled: use of the dust-free gowns and equipment equivalent to a specific clean room class and control of cleanliness. | | |

c) When using an assay procedure not described in the Handbook for Microbiological Inspection of Flight Instruments and Cleanrooms (JERG-0-057-HB004), a review by the Chairperson of Planetary Protection Review Board or a person designated by the Chairperson of Planetary Protection Review Board shall be conducted and approval shall be obtained. If the Chairperson of Planetary Protection Review Board deems it necessary, a further review shall be conducted by the Planetary Protection Review Board and approval shall be obtained from the Safety Review Board.

d) The number of samples required to estimate the bioburden for the flight hardware shall at least satisfy the following conditions and shall be agreed upon by the Chairperson of Planetary Protection Review Board.

1. At least one wipe sampling per 5 m2 shall be performed on each surface of the flight hardware that is greater than 1 m2.
2. At least one wipe sampling shall be performed on each surface of the flight hardware that is

greater than 0.1 m2 but not greater than 1 m2.

3. At least one swab sampling per 0.02 m2 of each surface of flight hardware not exceeding 0.1 m2 shall be performed.
4. At least one swab sampling of each surface of the flight hardware not exceeding 0.02 m2 shall be performed.

e) The method(s) for calculating surface bioburden and bioburden densities shall be agreed with the Chairperson of Planetary Protection Review Board.

f) Prior to applying the bioburden reduction procedures in Section 5.4.4, establish a procedure for evaluating bioburden using the procedures specified in Section 5.4.2a) or 5.4.2b).

#### 5.4.3 Biodiversity assessment

a) Biodiversity assessment on flight hardware and bioburden controlled environment(s) shall be performed using procedures D.3 to D.6 for Swab assays and procedures E.3 to E.6 for Wipe assays described in the Annex of Microbial Inspection Handbook for Flight Instruments and Clean Room (JERG-0-057-HB004).

#### 5.4.4 Bioburden reduction

a) For reduction of bioburden by dry heat sterilization, the provisions of the Sterilization Handbook for Flight Instruments (JERG-0-057-HB002) should be applied.
b) For the reduction of bioburden by hydrogen peroxide sterilization, the provisions of the Sterilization Handbook for Flight Instruments (JERG-0-057-HB002) should be applied.
c) The use of other methods of reducing bioburden shall be reviewed and approved by the Chairperson of the Planetary Protection Review Group or a person designated by the Chairperson of the Planetary Protection Review Group. If deemed necessary by the Chairperson of the Planetary Protection Review Committee, a further review shall be conducted by the Planetary Protection Review Committee and approved by the Safety Review Board.
d) The provisions of the Compatibility Test Handbook for Materials and Components for Sterilization Processes (JERG-0-057-HB005) shall be applied to the evaluation of the compatibility of materials and equipment for the implementation of the bioburden reduction process.

### 5.5 Requirement for documentation

a) In the case of a project subject to planetary protection, the planetary protection

implementation activities shall be addressed in the relevant project documentation
NOTE: For example, mission requirement, conceptual study report, procurement management plan, conceptual design
reports, system requirement, project plan (development policy and the development plan), development implementation organization, WBS, risk identification and the implementation plan, assumptions and constraints, quality management plan), systems engineering management plan, and their sub-documents, such as, verification management document, assembly, integration, test plans and verification plans, etc.

**Table 5.5-1: Planetary protection documentation**

| Documentation | Preliminary Version (Draft) | Final Version | Review Procedure | Reference DRD |
|---|---|---|---|---|
| Project Planetary Protection Requirements | MDR | SRR | Reviewed/approved by the Safety Review Board (SRB), after reviewed by the Planetary Protection Review Board (PPRB) | Annex A |
| Planetary Protection Plan | SRR | PDR | | Annex B |
| Planetary Protection Implementation Plan | PDR | CDR | | Annex C |
| Pre-launch Planetary Protection Report | PSR | LRR | | Annex D |
| Post-launch Planetary Protection Report | | within 6 months after the launch | Report to SRB after reviewed by the chair of PPRB | Annex E |
| | | Before transitioning to the Earth return phase | Report to SRB, after reviewed by the chair of PPRB. In the case of the plan changed, reviewed by SRB, after reviewed by PPRB. | |
| | | Before starting the atmospheric re-entry operations | | |
| | | Before unpacking the sample | | |
| Extended Mission Planetary Protection Report | In case of the mission changed | Mission Change Review | | Annex F |
| End-of-Mission Planetary Protection Report | | Within 12 months after the end of mission | Report to SRB, after reviewed by PPRB | Annex G |
| Organic Materials Inventory | CDR | LRR | Reviewed by SRB, after reviewed by PPRB | Annex H |

b) Project dedicated planetary protection documentation shall be provided in according to the matrix in Table 5.5-1:
NOTE Table 5.5-1 can be tailored to the respective project agreed upon with the chairperson of the Planetary Protection Review Board.

c) The Planetary Protection Officer shall prepare, in coordination with the Project Manager, the Agency level planetary protection report of a mission no later than six months of launch, in

addition, within 12 months after the end of the mission, and deliver it to the President of COSPAR and the chairperson of COSPAR Planetary Protection Panel. The materials shall be in English in principle.

NOTE: Contents of the JAXA level planetary protection report to COSPAR is described in the COSPAR Protection Policy (see Ref. [1]).

NOTE: In addition to the planetary protection report above, if the Planetary Protection Officer deems it necessary, the Planetary Protection Officer may report the result of each planetary protection reviews of the project to COSPAR.

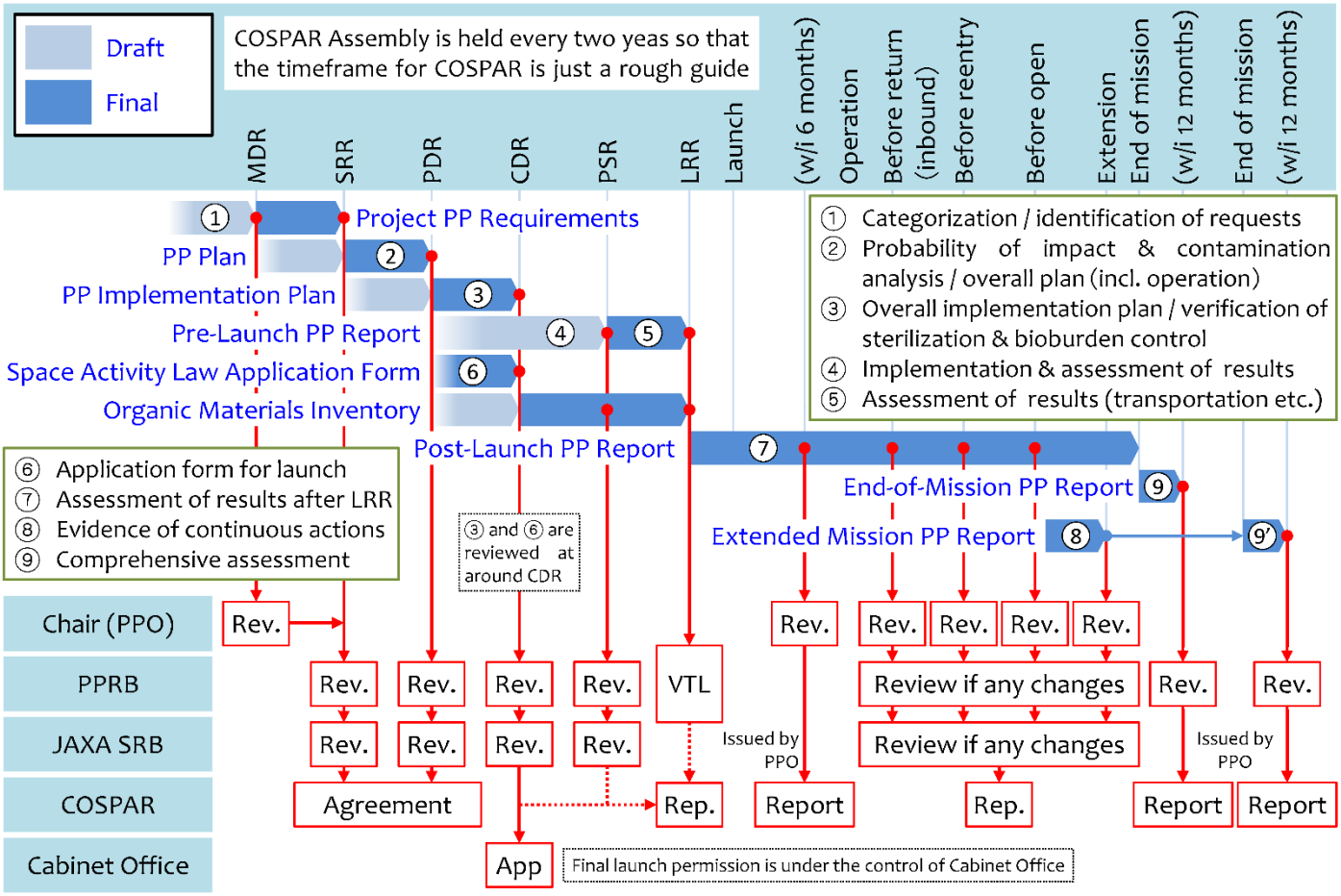


Figure 5.5-1 Planetary Protection Documentation and the review process.

### 5.6 Requirement for reviews

a) Planetary protection implementation activities and applicable planetary protection documentation as described in Table 5.5-1, including any documentation to support conclusions of the analysis, shall be reviewed at JAXA's regular review board and project reviews, with participation of the Chairperson of Planetary Protection Review Board (see Figure 5.5-1).

NOTE: The Chairperson of Planetary Protection Review Board, the person designated by the

Chairperson of Planetary Protection Review Board, or the Planetary Protection Review Board shall review documents through the project review process.
The project planetary protection requirement, the planetary protection plan, and the pre-launch planetary protection report are reviewed by the Planetary Protection Review Board.
The review result is reported to and obtained approval by the Safety Review Board.
NOTE: Additional reviews can be organization at the request and agreed as requested and agreed by Project Manager and the Chairperson of Planetary Protection Review Board.

b) The Chairperson of Planetary Protection Review Board or his or her representative shall participate to the LRR for projects with planetary protection constraints to review the status of the implementation of the planetary protection requirements prior to launch.
In the review, confirm the Safety Verification Tracking Log (VTL) in particular.

c) For return missions (see Section 3.1.20), planetary protection reviews shall be held to authorize the transition to a deferent segment of the return phase by the Chairperson of Planetary Protection Review Board or designated personnel assigned by the chairperson of Planetary Protection Review Board, prior to:
1. Leaving the target celestial body for return to Earth
2. Beginning atmospheric re-entry operations
3. Unpacking the returned sample

At the planetary protection reviews, the post-launch planetary protection report (Attachment E) updated after the post-launch planetary protection review shall be reviewed, and after the approval of the chairperson of the Planetary Protection Review Board, final approval of Senior Chief Officer of Safety and Mission Assurance Department must be obtained.
If it is recognized that a change or non-conformance of the planetary protection plan has occurred, the post-launch planetary protection report shall further be reviewed by the planetary protection review committee, and approval of the Safety Review Board shall be obtained.

NOTE 1: The purpose of these reviews is to ensure and demonstrate that the mission continues to meet the planetary protection requirements, and Earth safety in particular.

NOTE 2: The Planetary Protection Review is part of the regular project review.

d) Project manager and the Chairperson of Planetary Protection Review Board shall work together to develop documentation requirements to be applied for the review.

### 5.7 Nonconformances and waivers

a) The decision to dispose of nonconformances shall normative the defect management requirements of the Quality Assurance Program Standard (JMR-005) or the Quality Assurance Program Standard (Basic Requirements JIS Q 9100) (JMR-013).

b) In determining the disposition of nonconformity, implement a waiver application in accordance with the Configuration Management Standard (JMR-006) prior to the adoption of a disposition that does not conform to the requirements.

c) The approval of waivers affecting planetary protection requirements shall be subject to approval by the Chairperson of Planetary Protection Review Board.

d) For waiver approvals affecting system-level planetary protection requirements, shall be approve by the Planetary Protection Review Board first, then obtain approval of Senior Chief Officer of Safety and Mission Assurance Department.

e) Waiver approval of planetary protection requirements in the JAXA Program, in particular with the approval of the Safety Review Board.

## Annex A (normative) Project planetary protection requirements - DRD

### A.1. DRD identification

#### A.1.1 Requirement identification and source document

This DRD is based on the requirements of Sections 5.1a) and 5.5b) of this standard.

#### A.1.2 Purpose and objective

The purpose of the project planetary protection requirement document is to provide the set of the planetary protection requirements, tailored to the specific project, to be applied for industrial contracts such as manufacturers and operators.

### A.2 Expected response

#### A.2.1 Content

a) The project planetary protection requirement document shall include at least the following items:

1. Mission description
   (a) Scientific objectives, spacecraft overview and payload description
   (b) Mission type (e.g., fly-by, orbiter, lander, Earth return)
   (c) Description of mission phases
   (d) Description of launch vehicle and launch site
   (e) Identification of targeted and encountered Solar system bodies
   (f) Identification and use of nuclear heat and power sources, and these operation plan
   (g) Identification and use of aerobraking and aerocapture maneuvers, and the operation plan
   (h) Description of entry, descend and landing phases
   (i) Description of intended landing site and expected landing accuracy
   (j) Intended final disposition of all launched hardware
   (k) Description of international cooperation
2. Planetary protection category
3. Planetary protection management requirements
4. Technical planetary protection requirements
5. Planetary protection methods and procedures
6. Planetary protection documentation requirement
7. Planetary protection reviews
8. Nonconformance and waiver

#### A.2.2 Special remarks

a. Point 1 of A.2.1a) (Mission description) may be covered by a reference to another project document.

## Annex B (normative) Planetary protection plan – DRD

### B.1 DRD identification

#### B.1.1 Requirement identification and source document

This DRD is called from the requirement 5.5b) of this standard.

#### B.1.2 Purpose and objective

The planetary protection plan is the primary planning document describing how the project meets the planetary protection requirements. The planetary protection plan contains a consolidated planning for all mission phases involving all actors, including payload providers, launch service provider, and international partners for the applicable system architecture down to sub-system level.

### B.2 Expected response

#### B.2.1 Content

a) The planetary protection plan shall include the following items:

1. Mission description
2. Assessment of the consequences to implement the project planetary protection requirements w.r.t. design, development, schedule and operations
3. General implementation approach
    (a) Planetary protection management and organization
    (b) Description of bioburden control approach for all major flight hardware elements, including payload and launch recontamination
    (c) Description of bioburden allocations with clearly identified margins and uncertainties for all major flight hardware elements
    (d) Description of impact probability analysis, in accordance with the requirements 5.2.3, of this standard, including:
        (1) Impact analysis for launcher and spacecraft elements against target bodies identified in the “Project planetary protection requirements” document, with analysis supporting the conclusions providing evidence that the selected approach is feasible for the specific mission
        (2) If impact probability analysis is not possible or selected, break-up/burn-up and general atmospheric entry heating analysis providing evidence that the selected approach is feasible for the specific mission.
        Based on dry heat sterilization by aerodynamic heating, etc., it should be exposed to the environment at 500 ℃ or higher for 0.5 seconds or longer.
    (e) Description of contamination probability analysis, in accordance with the requirements 5.2.4 of this standard.
    (f) Description of the planetary protection procedures to be implemented in the project in

accordance with the requirements of Section 5.4 of this Standard.

(g) Description of planned requests for using methods, procedures or values not described in this standard, in accordance with the requirements of Section 5.7 of this standard.

4. Plan for planetary protection documentation and reviews, in accordance with the requirements of Section 5.5 and 5.6 of this standard.

5. Identify planetary protection activities and major milestone in the project schedule
6. Compliance matrix (compliance status table) against the project planetary protection requirements
7. Analysis and conclusions of significant impact for planned non-conformances or waivers
8. Verification matrix against the project planetary protection requirements

**B.2.2 Special remarks**

a. Point 1 of B.2.1a) may be covered by a reference to another project document.

b. Point 2 of B.2.1a) may summarize the consequences with references to other project documentation for detailed descriptions.

c. Points 6 and 8 of B.2.1.a) may be included in a project level compliance and verification matrix.

## Annex C (normative) Planetary protection implementation plan - DRD

### C.1 DRD identification

#### C.1.1 Requirement identification and source document

**This DRD is based on the requirements in Section 5.5b) of this standard.**

#### C.1.2 Purpose and objective

The purpose of the planetary protection implementation plan is to provide all relevant information about the detailed implementation (e.g. analysis, procedures and activities) of the planetary protection requirements in line with the planetary protection plan.

### C.2. Expected response

#### C.2.1 Content

a) The planetary protection implementation plan shall include the following items, however items that are unnecessary depending on the category can be omitted.
   1. Flight system description
      (a) Hardware description
         (1) System and sub-system description, including payload
         (2) Planetary protection description vs. subsystem names
      (b) Criteria for exposed surfaces definition and planetary protection accountable volumes
      (c) Mission planetary protection activities as they are intended to be implemented, accounting for the following data:
         (1) Impact probability analysis, in accordance with the requirements of Section 5.2.3 of this standard
         (2) Contamination probability analysis in accordance with the requirements of Section 5.2.4 of this standard
         (3) Spacecraft induced special regions, in accordance with requirements of Section 5.3.2.2.2c) of this Standard
         (4) Landing site selection
         (5) Draft Organic Materials Inventory (Exhibit H) in accordance with the requirements of Section 5.2.5 of this Standard
   2. Description of Facilities
      (a) Formal system

(1) Risk assessment
(2) Alert and action levels
(3) Control approach

(b) Commissioning

(c) Operation

3. Bioburden control plan for the flight system

(a) Bioburden allocation
(1) Exposed surface bioburden allocation
(2) Total bioburden allocation
(3) Hardware exceptions

(b) Sampling/ Assay plan
(1) Fraction of exposed surfaces sampled
(2) Number of samples
(3) Sampling site selection
(4) Sampling schedule

(c) Statistical treatment of the assay results
(1) Case for total bioburden count of two or more
(2) Case for total bioburden count of zero or one
(3) Case for treatment of bulk assay
(4) Criteria for bioburden density standard deviation
(5) Assay results acceptance guidelines
NOTE: In this article, it is referred Microbial assay Handbook for flight hardware and clean rooms (JERG-0-057-HB004). The example in Annex H of the Handbook is helpful.

(d) Bioburden assessment, in accordance with the requirements of Sections 5.4.1 and 5.4.2 of this Standard;
(1) Procedure for calculating the surface bioburden density and bioburden number of flight hardware with assay data.
(2) Procedure for calculating the surface bioburden density and bioburden number of flight hardware without assay data.
(3) Expected surface bioburden density and bioburden number of flight hardware treated by a bioburden reduction procedure
(4) Procedure for calculating the encapsulated bioburden density and bioburden number of flight hardware with assay data
(5) Procedure for calculating the encapsulated bioburden density and bioburden number of flight hardware without assay data

(e) Biodiversity assessment, in accordance with the requirements of Section 5.4.3 of this Standard.

4. Bioburden reduction plan for the flight system, in accordance with the Requirements of Section

5.4.4 of this Standard

(a) Spacecraft hardware list subject to bioburden reduction processes

(b) Process analysis

(c) Process control and verification plan

(d) Method for preventing recontamination

(e) Approach in case of recontamination occurs

5. General implementation approach for the flight system

(a) Pre-assembly, integration and testing (AIT) & launch operations

(1) General approach at hardware manufacturing sites

(2) General approach at prime/subcontractor/instrument provider site

(b) Assembly, integration and testing (AIT) & launch operations

(1) Acceptance criteria

(2) General approach at prime/subcontractor/instrument provider site

(3) General approach at test site

(4) General approach at launch site

(c) Control of inside surface of the launch vehicle fairing, launch vehicle air conditioning, and satellite assembly building air conditioning

(d) Upper stage of launch vehicle and propulsion module (kick motor)

6. Updated list of the foreseen waivers/non-conformance reports (NCRs) and the associated impact analysis.

**C.2.2 Special remarks**

None.

## Annex D (normative) Pre-launch planetary protection report - DRD

### D.1 DRD identification

#### D.1.1 Requirement identification and source document

This DRD is based on the requirements in Section 5.5b) of this standard.

#### D.1.2 Purpose and objective

The purpose of the pre-launch planetary protection report is to ensure whether the project meets the planetary protection requirements, in particular bioburden allocation based on routine and verification assay results, before the flight hardware is shipped to the launch site.

### D.2 Expected response

#### D.2.1 Content

a) The pre-launch planetary protection report shall include the following items:

1. Deviations from planetary protection requirements and plan.
2. Deviation from the planetary protection implementation plan.
3. Results of contamination control measures, including raw and processed data of bioburden assays for the entire product tree.
4. Update of impact probability analysis, in accordance with the requirements of Section 5.2.3 of this standard.
5. Update for contamination probability analysis, in accordance with the requirements of Section 5.2.4 of this Standard.
6. Organic materials inventory, in accordance with the requirements of Section 5.2.5 of this Standard (Exhibit H).
7. Conclusion.

#### D.2.2 Special remarks

None.

## Annex E (normative) Post-launch planetary protection report - DRD

### E.1 DRD identification

#### E.1.1 Requirement identification and source document

This DRD is based on the requirements in Section 5.5b) of this standard.

#### E.1.2 Purpose and objective

The purpose of the post-launch planetary protection report is to account for effects of events from submission of the pre-launch planetary protection report.

### E.2 Expected Response

#### E.2.1 Content

a) The post-launch planetary protection report shall include the following items:

1. Ground processing affecting bioburden control.
2. Final verification assay results.
3. Launch events affecting bioburden control.
4. Post-launch events withing the range of deployment and commissioning in orbit.
5. Conclusion.

#### E.2.2 Special remarks

None.

## Annex F (normative) Extended mission planetary protection report-DRD

### F.1 DRD identification

#### F.1.1 Requirement identification and source document

This DRD is based on the requirements in Section 5.5b) of this standard.

#### F.1.2 Purpose and objective

The purpose of the extended mission planetary protection report is to provide evidence that demonstrates the continue compliance with planetary protection requirements, taking into account the activities identified for extended mission phase.

### F.2 Expected Response

#### F.2.1 Content

a) The extended mission planetary protection report shall include the following items:

1. Deviations from planetary protection requirements and plans.
2. Deviation from the planetary protection implementation plan.
3. Updates of impact probability analysis, in accordance with the requirements of Section 5.2.3 of this standard.
4. Updates for contamination probability analysis, in accordance with the requirements of Section 5.2.4 of this Standard.
5. Conclusion.

#### F.2.2 Special remarks

None.

# Annex G (normative) End-of-mission planetary protection report - DRD

## G.1 DRD identification

### G.1.1 Requirement identification and source document

This DRD is based on the requirements in Section 5.5b) of this standard.

### G.1.2 Purpose and objective

The purpose of the end-of-mission planetary protection report is to describe the degree to which the project has met the planetary protection requirements throughout the complete mission.

## G.2 Expected Response

### G.2.1 Content

a) The end-of-mission planetary protection report shall include the following items:
1. Disposition and condition of all launched flight hardware including the launcher upper stage, either in space describing the orbital parameters or for landed/impacting elements by position on the target body
2. Deviation from planetary protection requirements and plan.
3. Deviation from planetary protection implementation plan.
4. Update of impact probability analysis in accordance with the requirements of Section 5.2.3 of this standard.
5. Update for contamination probability analysis, in accordance with the requirements of Section 5.2.4 of this Standard.
6. Conclusion.

### G.2.2 Special remarks

None.

## Annex H (normative) Organic Materials inventory - DRD

### H.1 DRD identification

#### H.1.1 Requirement identification and source document

This DRD is based on the requirements of Section 5.2.5 of this standard.

#### H.1.2 Purpose and objective

The purpose of organic materials inventory is to document the organic material on the spacecraft.

### H.2 Expected Response

#### H.2.1 Content

a) The Organic Materials Inventory shall include the following for each organic material present above a specified limit:
   1. Identity
   2. Chemical composition.
   3. Usage w.r.t. product tree.
   4. Mass. estimate
   5. Ratings and reference for outgassing for each item in compliance with Contamination Management Standard (JMR-010)
   6. Supplier for each item

b) For lunar landing missions, a description of the products released by the propulsion and life-support system, as applicable, into the lunar environment shall be provided, including:
   1. A quantitative and qualitative description of the major chemical species, and
   2. An indication of the minor chemical species and quantity

#### H.2.2 Special remarks

None.

**Annex I (informative) Guidelines for human Mars missions**

Whether the mission to Mars is carried out by robots or humans, the intent of the Planetary Protection Policy is identical.
Therefore even manned missions to Mars should not be relaxed with the goal of planetary protection.
Rather, even if the specific implementation requirements are different, all the mitigation should not be relaxed.
The general principles are as follows:

- Top policy of planetary protection in Mars missions is to protect the planet from potential backward pollution.
- Contributing to astrobiological exploration on Mars can only be done if human-related pollution can be managed and understood.
- In a landing mission that performs surface activities, all processes and mission operations related to humans cannot be completed in a fully closed system.
- Crews and support systems exploring Mars will inevitably be exposed to Martian material.

In accordance with these principles, specific implementation guidelines for manned missions to Mars are as follows:

- Various types and quantities of microbial communities will be carried on board in manned missions.
  It is not realistic to prescribe all of the acceptable microbial communities and contamination risks at launch.
  Once the launch baseline conditions are defined and met, continuous monitoring and evaluation methods of microorganisms carried by manned missions are needed to address the issue of forward and backward contamination.
- In preparation for the possibility of contact with life on Mars, have the ability to isolate all crew members and individual crews during and after missions.
- Develop comprehensive planetary protection protocols to address forward and backward contamination in manned missions, which include subsurface exploration and sample handling, and the coordinated operation of manned and unmanned exploration in the return of samples and crews to Earth.
- Neither unmanned nor manned exploration shall contaminate the special region of Mars (see Section 3.1.23).
- Prior to manned exploration, a preliminary survey shall be conducted by unmanned exploration. The preliminary survey may be a preliminary unmanned exploration mission,

or a survey by a prior unmanned exploration mission within a manned mission.

- Untreated samples taken from unknown or special regions on Mars or the sampling instrument should be treated according to proper handling and testing protocols which developed based on the latest planetary protection category V, "Restricted Return to Earth (see Section 3.1.13)".
- The crew of a manned mission shall have primary responsibility for the implementation of planetary protection that affects the crew during the mission.
- The planetary protection requirements in early manned missions, as well as the crew support system, should take a safer approach, given the insufficient knowledge of the Martian environment and the possibility of life.
- The need for planetary protection in early manned missions was to have knowledge of the Martian environment and the potential for life. Planetary protection requirements for subsequent missions shall not be relaxed without scientific review, legitimacy, and consensus.

## Annex J (Informative) Category Selection Flow Chart/ List of Planetary Protection Requirements by Category

The flowchart shown in Figure J-1 can be used to determine which planetary protection category each mission falls into. Table J-1 can be used to review the target body and planetary protection requirements for each category. However, the following points should be noted.

a) Planetary protection categories may be revised from time to time as scientific knowledge improves, based on the latest scientific evidence. This flowchart is current as of October 2020.

b) For any bodies not listed here, or for any small bodies of any spectral type, the presence or absence of Earth return restriction will be judged on a "case-by-case" basis for Category V.

c) For P and D type small bodies, the default is a restricted Earth return (see Section 3.1.13) "due to lack of scientific knowledge" at present, and the decision in Section b above is then applied to each mission.

d) The conditions for orbital arrival and ground arrival include not only the nominal case but also the off-nominal case. In other words, if a spacecraft does not reach the orbit (ground) of the celestial body in the nominal plan, but may reach the orbit (ground) due to a defeat or other reason, it is treated as having reached the orbit (the ground arrival).

e) The Earth’s Moon is considered to be part of the Earth-Moon system and the return restriction includes the Moon as well as the Earth.

f) The rules for outbound and inbound routes to Ocean World (Europa, Enceladus, etc.) will be revised within a few years through the ongoing PPOSS activities as of November 2018, and the current situation is provisional.

g) On the surface of Mars, Category IV is further subdivided according to whether or not that it is equipped with an observation device for life exploration and whether or not it has access to a special area (see Section 3.1.23).

h) In the case of a spacecraft reaching the orbits of multiple bodies, all applicable criteria shall be applied.

Table J-1: Planetary Protection Category and Outline of Planetary Protection Requirements

| Cat. | Target Mission | Target Body | Planetary Protection Requirements |
|---|---|---|---|
| I | All types of missions to a target body that has no significant scientific interest in the process of chemical evolution and the origins of life. | S-type asteroids, Io, Mercury. | None |
| II | All types of missions to a target body that has significant scientific interest in the process of chemical evolution and the origins of life but for which scientific opinion is that there is only a remote chance that contamination by a spacecraft could compromise future investigations. | (II-1)Venus, Comets, asteroids (P, D, and C-type), Jupiter, Jovian moons (except Io, Europa and Ganymede), Saturn, Saturnian moons (except Titan and Enceladus), Uranus, Uranian moons, Neptune, Neptunian moons (except Triton), Kuiper Belt Objects < ½ size of Pluto. | Simple documentation tailored to planetary protection requirements |
| | | (II-2) Moon<br>II: Moon orbiting and flyby missions<br>IIa: Landing missions that are not IIb<br>IIb: Landing missions to the permanently shadowed area or polar region | Organic materials inventory in addition to (II-1) (However, it is not required in II, and organic products released from the propulsion system are covered in IIa) |
| | | (II-3) Ganymede, Titan, Triton, Pluto/Charon, Kuiper Belt Objects > ½ size of Pluto. | Contamination probability analysis in addition to (II-1) |
| III | Fly-by and orbiting missions to solar system bodies to be protected. | Mars, Europa, Enceladus | Detailed documentation based on planetary protection requirements, organic materials inventory, impact probability analysis, and contamination probability analysis. |
| IV | Surface missions to solar system bodies to be protected. | | Detailed documentation, organic materials inventory, storage of organic samples, sterilization and bioburden control for a large number of materials, parts, assemblies and facilities. |
| V | All Earth-return missions from solar system bodies deemed to have no indigenous life forms.: Unrestricted Earth Return | Venus, Moon, asteroids (P, D, and C-type), Io, Mercury. However, small objects will be judged on a case-by case basis. | Only the planetary protection requirements that correspond to the outbound itinerary category |
| | Earth-return missions other than the above: Restricted Earth Return | Mars, Europa, Enceladus.<br>Other than the above will be judged on a case-by case basis. | Sterilization and assessment. If assessment is not possible, complete containment. |

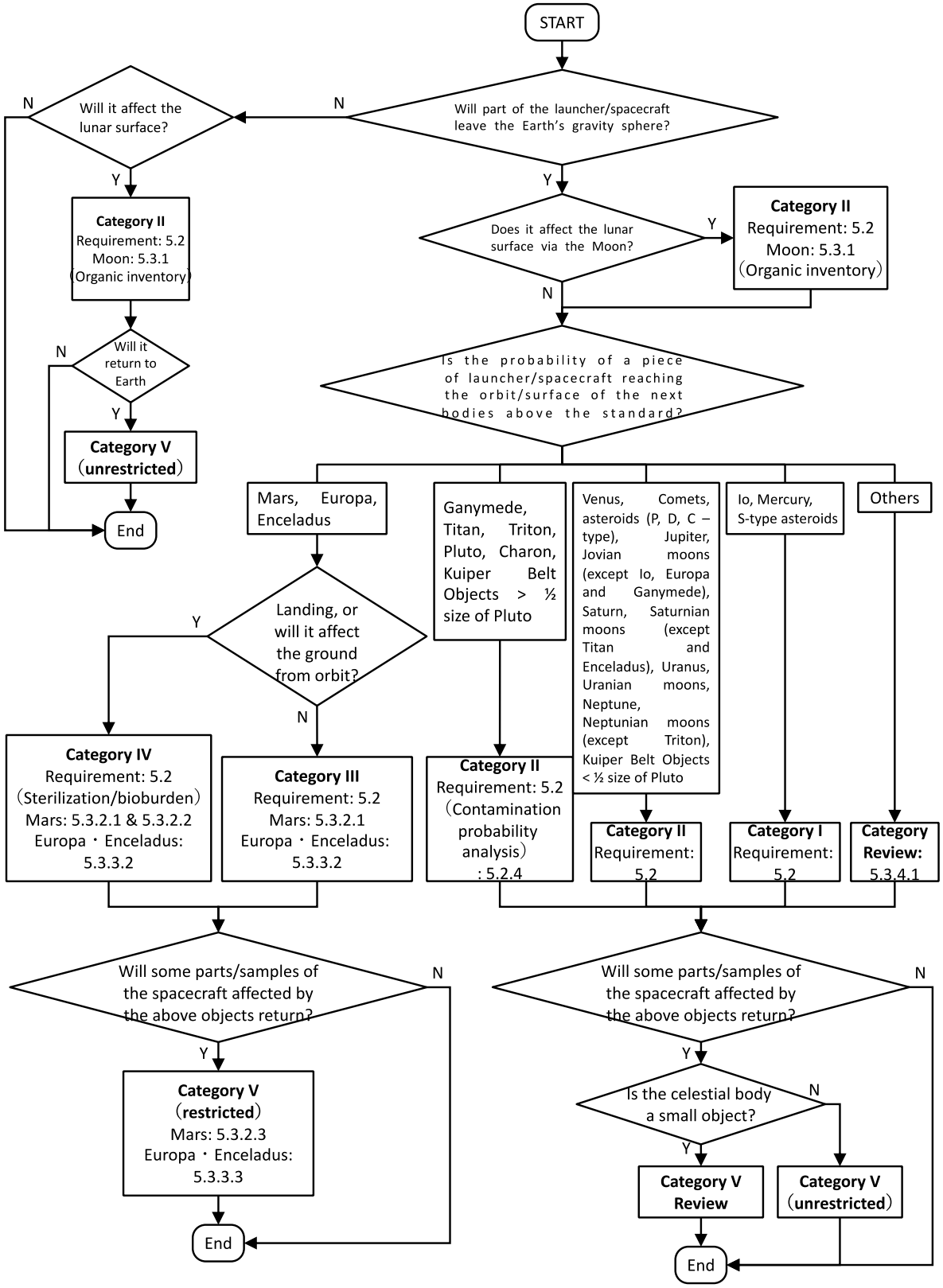


Figure J-1: Flow chart of mission category (As of February 2022)

## Annex K (Informative) Task examples by category

### K.1 Task examples of categories I and II

As an example of the task of Category II (same for Category I), planetary protection implementation for C-type NEO/Ryugu exploration (* corresponding to the outbound journey of the Hayabusa2 project) is shown below.

#### K.1.1 Confirmation of planetary protection requirements for the project

The outbound journey of the Hayabusa2 project corresponds to Category II. The identified planetary protection requirements for the project are as follows.

a) For any component of the spacecraft, such as the upper stage of a launch vehicle, that is not assembled or stored under controlled conditions in a constantly operating ISO Class 8 or better cleanrooms, the probability of impact on Mars shall be less then $1x10^{-4}$ for the first 50 years after launch (see Section 5.2.3b).
b) For any component of the spacecraft assembled and stored in constantly operating ISO Class 8 or better cleanrooms, the probability of impact on Mars shall be less than $1x10^{-2}$ for the first 20 years after launch. In addition, it shall be less than $5x10^{-2}$ for the period from 20 to 50 years after launch (see section 5.2.3c).

#### K.1.2 Task contents

The tasks for the planetary protection requirements for the project in Section K.1 are impact probability analysis and documentation (reference [5]). An example of impact probability analysis is shown below (see JERG-0-057-HB001 for details).

##### K.1.2.1 Example of response to planetary protection requirements for the project a

a) Perform an orbital analysis using the Monte Carlo method including the following items, and achieve a 99% confidence level.
   1. Perform an orbit analysis on all candidate orbits in the launch window.
   2. The number of the Monte Carlo trial calculations is adjusted according to the number of impacts detected.
b) Factors to be included in the analysis
   1. Gravity perturbation by Sun, Earth, Moon, Venus, Mercury, Jupiter, Saturn
   2. Solar radiation pressure (SRP) in uncontrolled attitude
   3. If there is an upper stage after the spacecraft is released, the reliability of this maneuver must be included in the overall analysis.

##### K.1.2.2 Example of response to planetary protection requirements for the project b

a) Perform an impact probability analysis of the spacecraft during cruising from the Earth to the target small body will be performed including the following items.
      1. Perform it in both nominal and off-nominal flight conditions and analyze the spacecraft

orbit including the modules to be released.

2. Achieve a 99% confidence level using Monte Carlo method.
3. Input the rocket dispersion matrix.
4. Consider gravity perturbations by the Sun, Earth, Moon, Venus, Mercury, Jupiter, and Saturn.
5. Consider the solar radiation pressure (SRP) in controlled and uncontrolled attitudes.

b) If the probability of impact exceeds the specified value, the failure probability of the spacecraft shall be analyzed in consideration of the following items and reflected in the orbit analysis.

1. Reflect the reliability of the onboard equipment and the operational reliability required to control the spacecraft.
2. Reflect the effects of meteoroid impacts.
3. Reflect the failure probability of the spacecraft in the collision trajectory probability.

### K.1.3 Schedule example

An example of a Category II planetary protection schedule is shown in Table K-1, using Hayabusa2 as an example.

Table K-1: Example of a Category II planetary protection schedule (Hayabusa2)

| Schedule<br>(Based on the launch day) | Item | Approval/ Review | Overview / Reference |
|---|---|---|---|
| About 6 years before | Planetary protection requirements for the project (draft) | MDR | Annex A |
| About 5 years before | - Planetary protection requirements for the project (final)<br>- Planetary protection plan (draft) | SRR | Annex B |
| About 5 years before | - Transition to project | Review of Project Transition | |
| Up to PDR | - Impact probability analysis<br>- Contamination probability analysis | | Section 5.2.3 and 5.2.4 in this standard.<br>JERG-0-057-HB001 |
| About 4 years before | - Planetary protection plan (final) | PDR | Annex B |
| About 3 years before | Report on category proposals to NAC/PPS. | NAC/PPS | Outbound category II, Inbound category V a)<br>(Annotation: This item is conducted due to a joint mission with NASA.) |
| About 3 years before | Conduct a review meeting for category proposals from JAXA at the COSPAR Colloquium. | COSPAR planetary protection panel | Outbound category II, Inbound category V a) proposal |
| About 2 and half years before | Approval planetary protection requirement at the COSPAR general meeting. | COSPAR planetary protection panel | Outbound category II, Inbound category V a) confirmed |
| About 8 months before | Report to NAC/PPS | NAC/PPS | Report on impact probability analysis and implementation plan.<br>(Annotation: This item is conducted due to a joint mission with NASA.) |
| About 4 months before | Report on planetary protection plan at the COSPAR. | COSPAR planetary protection panel | Report on impact probability analysis and implementation plan. |

| Schedule<br>(Based on the launch day) | Item | Approval/ Review | Overview / Reference |
|---|---|---|---|
| About 1 week before | - Pre-launch planetary protection report (final) | LRR | Annex D |
| Launch day | Launch | | |
| No later than 6 months after launch | Post-launch planetary protection report (final) | No later than 6 months after launch | Annex E |
| To the end-of-the mission.<br>COSPAR general meeting<br>(Every 2 years) | Planetary protection achievements report at COSPAR general meeting.<br>(Using pre-launch/post-launch planetary protection reports, extended-mission planetary protection reports, end-of-mission planetary protection report, etc.) | COSPAR planetary protection panel | planetary protection achievements report |
| Until the start of the extended mission. | Planetary protection report on the extended mission. (Final) | Extended mission review | Annex F |
| No later than 6 months after the end-of-mission. | End-of-mission planetary protection report. (Final) | No later than 6 months after the end-of-mission. | Annex G |

* Now that the Planetary Protection Officer has been established, these processes are replaced by coordination by the Planetary Protection Officer, review by the Planetary Protection Review Board, and reporting of the review results.

## K.2 Task examples of category III

As an example of a category III task, an example of planetary protection of ExoMars Trace Gas Orbiter (TGO) is shown below (Reference [6]).

### K.2.1 Confirmation of planetary protection requirements for the project

In this example, which classified as Category III, the identified planetary protection requirements for the project are as follows:

a) For any component of the spacecraft, such as the upper stage of a launch vehicle, that is not assembled and stored under controlled conditions in a constantly operating ISO class 8 or better cleanrooms, the probability of impacts on Mars shall be ≤ $1x10^{-4}$ for the first 50 years after launch (see Section 5.2.3b).

b) One of the following conditions has to be satisfied (see Section 5.2.3c).

1. For any component of the spacecraft assembled and stored in constantly operating ISO Class 8 or better cleanrooms, the probability of impact on Mars shall be less than $1x10^{-2}$ for the first 20 years after launch. In addition, it shall be less than $5x10^{-2}$ for the period from 20 to 50 years after launch.
2. The bioburden of the entire spacecraft, including surfaces, joint surfaces, and embedded items, should not exceed $5x10^{+5}$ spores.

### K.2.2 Task contents

Here is an example of a task that satisfies 1 of the conditions in Section K.2.1b). In this case, the tasks for the planetary protection requirements for the project in Section K.2.1 are impact probability analysis and the documentation (reference [6]).

An example of an impact probability analysis is shown below (see JERG-0-057-HB001 for details).

#### K.2.2.1 Example of response to planetary protection requirements for the project a (example of TGO)

a) Perform an orbital analysis using Monte Carlo method, including the following items, and achieve a 99% confidence level.
   1. Perform an orbit analysis on all candidate orbits in the launch window.
   2. The number of the Monte Carlo trial calculations is adjusted according to the number of impacts detected.

b) Factors to be included in the analysis
   1. Gravitational potential of Earth / Mars and gravitational perturbation by third celestial bodies (Sun, Moon, Jupiter, Saturn).
   2. Solar radiation pressure (SRP) in uncontrolled attitude.

3. Thrust discharge for the direction of travel, degassing for all directions.
4. If there is an upper stage maneuver after the spacecraft is released, the reliability of this maneuver must be included in the overall analysis.

**K.2.2.2 Example of response to planetary protection requirements for the project b.1 (example of TGO)**

a) The final stability analysis of the orbit for scientific observation will be carried out, including the following items, to clarify that the orbit will be stable for more than 50 years.
   1. Numerical propagation of orbits due to atmospheric fluctuations by solar cycle activity, etc.
   2. Evaluation of appropriate ballistic coefficients and parameters obtained from the atmospheric model.

b) Impact probability analysis of the spacecraft before the Deep Space Maneuver (DSM) is carried out, including the following items, to clarify that the spacecraft will not collide for more than 50 years.
   1. Demonstrate that the impact probability requirement is satisfied statistically using Monte Carlo method, etc.
   2. Use the rocket dispersion matrix as an input.
   3. Gravitational potential of Earth and Mars and the gravitational perturbation of the third celestial body (Sun, Moon, Jupiter, Saturn) are considered.
   4. Solar radiation pressure (SRP) in an uncontrolled attitude is considered.

c) Impact probability analysis is performed for the orbiting target celestial body during its arrival from the DSM to the final orbit, including the following items. (Please refer to JERG-0-057-HB001 for details as it is just an example of TGO.)
   1. (On the conservative side) The orbital impact probability is assumed to be 1, if the spacecraft flies straight into ballistic flight after DSM.
   2. Reflect the reliability of onboard equipment and operational reliability required to control the spacecraft is reflected. (PHW, fail)
   3. Reflect atmospheric variabilities during the Mars aerobrake phase is reflected. (Ignore the possible recovery on the conservative side.) (POP.fail)
   4. Reflect meteoroid impacts and their effects are reflected (see section K.2.2.2d)).

   Impact probability = PHW,fail + POP,fail + Pmet,fail ≦1 %

d) Define the meteoroid model by considering the following items.
   1. Selection of meteoroid flux (number of particles per unit time and unit volume) model (example: Grun model)
   2. Velocity distribution (e.g., 20 km / s)
   3. Meteoroid density (e.g., 2.5 g / $cm^3$)
   4. Average impact angle (e.g., 45 degrees)

e) Analysis of results
   1. Selection of critical equipment for spacecraft control.

2. Assessment of protection by MLI, panel, honeycomb panel, etc.
3. Assessment of protection in terms of distances between different materials using appropriate ballistic limit calculation methods (BLE, IADC).
4. Assessment of critical equipment failure mode.
5. Assessment of problem-prone equipment that is prone to problems (e.g., tanks, star trackers, propulsion systems, UHF RFDN waveguides, etc.).

### K.2.3 Schedule example

See Table K-1 for the planetary protection schedule in this case.

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