Planetary Protection of Outer Solar System bodies
- PPOSS -
Go to https://www.menti.com/ on your mobile phone or computer and use the code 78 35 64

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Planetary Protection of Outer Solar System bodies
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• PPOSS is supported by the European Commission Horizon 2020 programme for three years (2016-2018) under Grant Agreement 687373

• Seven Contractual Partners
  • European Science Foundation – ESF, France (Coordinator)
  • German Aerospace Center – DLR, Germany
  • Committee on Space Research – COSPAR, France
  • Eurospace, France
  • National Institute for Astrophysics – INAF, Italy
  • Space Technology Ireland Limited – STIL, Ireland
  • Imperial College of Science, Technology and Medicine – IC, UK
Planetary Protection is an issue of global relevance

- PPOSS is supported under the ‘International Collaboration’ 2014 Work Programme item
- International Partner organisations are full members of the PPOSS team
  - Sit in the project Steering Committee
  - Support the participation of experts to the various events
  - Host PPOSS seminars
  - …
- One international partner completed MoU
  - China Academy of Space Technology (CAST)
- One international organisation with regular and fruitful interactions
  - Japan Aerospace Exploration Agency (JAXA)
- One international observer
  - Office of the Space Studies Board of the US National Academies of Sciences, Engineering and Medicine – Contact point David Smith
Ganymede

- Polar frost
- Saltwater ocean
- Tetragonal Ice (VI)
- Rocky mantle
- Iron & iron sulfide core (liquid)
- Iron core (solid)
- Crater
- Light terrain
- Dark terrain
- Grooves
Planetary Protection Regulation

- The meticulous process of determining planetary protection regulations for a specific mission depend on:
  - the target body (e.g. Mars vs the Moon)
  - the type of encounter (e.g. Orbiter vs Lander)
  - specific goals (e.g. to see if the target body has/had life)

- Each mission presents unique contamination challenges and therefore has different requirements

- Planetary Protection Officer/Agencies will determine specific requirements for a mission and classify it into a Mission category(s) – **With support from the scientific community**
<table>
<thead>
<tr>
<th>Mission Category</th>
<th>Mission Type</th>
<th>Planetary Bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Any</td>
<td>Bodies not of direct interest for understanding the process of chemical evolution or the origin of life. No protection of such planets is warranted</td>
</tr>
<tr>
<td>II</td>
<td>Any</td>
<td>Bodies of significant interest relative to the process of chemical evolution and the origin of life, but only a remote chance that contamination could compromise future investigations</td>
</tr>
<tr>
<td>III</td>
<td>Flyby, orbiter</td>
<td>Bodies of significant interest to the process of chemical evolution and/or the origin of life, and where scientific opinion provides a significant chance that contamination could compromise future investigations</td>
</tr>
<tr>
<td>IV</td>
<td>Lander, Probe</td>
<td>Bodies of significant interest to the process of chemical evolution and/or the origin of life, and where scientific opinion provides a significant chance that contamination could compromise future investigations</td>
</tr>
<tr>
<td>V (unrestricted)</td>
<td>Earth Return</td>
<td>Earth-return missions from bodies “deemed by scientific opinion to have no indigenous life forms.”</td>
</tr>
<tr>
<td>V (restricted)</td>
<td>Earth Return</td>
<td>Earth-return missions from bodies deemed by scientific opinion to be of significant interest to the process of chemical evolution and/or the origin of life.</td>
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</tbody>
</table>
The Case of Mars

• Mars missions have specific set of requirements

• Category III:

  • The probability of impact on Mars by any part of the launch vehicle (e.g., upper stage) shall be $<1 \times 10^{-4}$ for the first 50 years after launch

  • One of the following conditions shall be met:
    • The probability of impact on Mars by any part of a spacecraft is $<1 \times 10^{-2}$ for the first 20 years after launch, and $<5 \times 10^{-2}$ for the time period from 20 to 50 years after launch
    • The total bioburden of the spacecraft, including surface, mated, and encapsulated bioburden, is $<5 \times 10^5$ bacterial spores
The Case of Mars

- Mars missions have specific set of requirements

- Category IV:
  - Missions that are designed to reach Mars’ surface (i.e., Lander, Probe)
  - **IVa**: Lander systems not carrying instruments for the investigations of extant Mars life
  - **IVb**: Lander systems designed to investigate extant Martian Life
  - **IVc**: Missions investigating Martian special regions, even if they do not include life detection experiments. Martian Special Regions include those within which terrestrial organisms are likely to replicate and those potentially harboring extant Martian Life
The Case of Mars

• All landers to Mars must carry $< 5 \times 10^5$ heat-resistant organisms (‘spores’) in total (surface, mated, and embedded), and $< 3 \times 10^5$ on exposed surfaces, distributed at $< 300$ ‘spores’ per m$^2$.

• Category IVb missions comprise lander systems carrying instruments designed to investigate extant Martian life, and must meet either of these more stringent requirements:
  • Exposed surfaces of the entire landed system must be cleaned and treated to produce a 4 decade reduction in the above levels, or to levels driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent.
  OR
  • All surfaces that may contact the samples must be cleaned and treated to produce a 4 decade reduction, and a method to prevent recontamination be in place. Modelling must demonstrate a low probability of recontamination from untreated hardware.
The Case of Mars

Cat. IVc - In addition to requirements for Cat Iva

If the landing site is within the special region, the bioburden of the entire surface system shall be <30 bacterial spores on exposed internal and external surfaces

One of the following conditions shall be met:

• The bioburden of the entire surface system is <30 bacterial spores on exposed internal and external surfaces if the special region is accessed through horizontal (e.g., roving) or vertical mobility (e.g., drilling)

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

If an off-nominal condition (such as a hard landing) can cause a high probability (>10^{-2}) of inadvertent biological contamination of the 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 (surface, mated, and encapsulated) bioburden level shall be ≤ 30 + 1.5 \times 10^{4} bacterial spores
The case of Europa

• Missions to Europa

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

CATEGORY III/IV/V REQUIREMENTS FOR EUROPA

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

⇒ Except the estimation of the bioburden at launch all other factors are unknown!

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

Sample Return Missions from Europa

Category V. The Earth return mission is classified, “Restricted Earth return.”
Focuses on and is mostly articulated around biological contamination...

...although PPP recommends organic inventory and Mars 2020 addresses organic contamination sets quantitative guidelines.
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<th>COSPAR Category</th>
<th>Lead Agency, Country</th>
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<td>III</td>
<td>NASA, US</td>
<td>Ongoing</td>
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<tr>
<td>Rosetta</td>
<td>Comet C-G, Asteroid Lutetia</td>
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<td>Juno</td>
<td>Jupiter</td>
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<td>Hayabusa 2</td>
<td>Asteroid 1999 JU3</td>
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<tr>
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<td>II</td>
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<td>Europa and Jovian System</td>
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# Programmatic Landscape

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![Graphical representation of missions](image-url)
Some say:

Asteroids Will Unlock The Solar System’s Economy.

The local resources of space, such as the abundant frozen water on asteroids and comet nuclei, could be a key to replenishing Earth’s resources, allowing for sustainable development for centuries to come.
Sooner or later...

...new missions will orbit, land and return samples from these targets

• An increasing number of countries will be involved
• These missions will likely investigate the presence of organics

Planetary Policy issues should be carefully considered
To provide an international forum to consider and approach the specificities of Planetary Protection (biological and organic contamination) for outer Solar system bodies, including small Solar system bodies, in the general context of Planetary Protection regulation and to provide recommendations to COSPAR.
Describe the state of the art and good practice for implementing planetary protection requirements, identify good practices and lessons to be learnt.

Describe the state of the art and good practices to implement planetary protection requirements in the form of a handbook, including a historical perspective, up-to-date implementation measures, identification of problems and how to solve them, lessons learnt, and aspects related to international cooperation (i.e. joint missions).
PPOSS Objective 1

Describe the state of the art and good practice for implementing planetary protection requirements, identify good practices and lessons to be learnt.

- International Planetary Protection Handbook -

A historical perspective, up-to-date implementation measures, identification of problems and how to solve them, lessons learnt, and aspects related to international cooperation (i.e. joint missions).
PPOSS Objective 1

- International Planetary Protection Handbook –
  - Planetary Protection Requirements
  - Planetary Protection Challenges in Organic Contamination
  - Lessons Learned and Case Studies - How to comply with Planetary Protection Standards
  - Planetary Protection Check List
Identify scientific challenges, scientific requirements and knowledge gaps related to planetary protection of outer solar system bodies, including small solar system bodies.

In the context of the current and foreseen/foreseeable programmatic landscape, identify the many challenges, critical expertise as well as knowledge gaps raised by planetary protection related to i) biological contamination of outer solar system bodies, including small solar system bodies and ii) organic contamination of outer solar system bodies, including small solar system bodies. Propose planetary protection requirements based on scientific grounds, suggest activities to overcome the main hurdles and to fill-in knowledge gaps.
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PPOSS Objective 2

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- PPOSS Science White Book –

• What are the main differences between Mars and Ocean/Icy worlds (e.g. new model organisms)?
• How to bridge the gaps?
PPOSS Objective 3

Develop an European engineering roadmap

Based on the scientific requirements and recommendations, identify critical technologies required to best address planetary protection of outer solar system bodies, including small solar system bodies, define their availability and readiness level in Europe, suggest a roadmap covering the next 15-20 years.
PPOSS Objective 3

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PPOSS Objective 3

- European Engineering Roadmap –

• What techno requirements are required to cope with the specifics of Ocean/Icy worlds?
PPOSS Objective 4

**Review of the international outer solar system planetary protection regulation structure, process and categorisation, suggest improvements**

In the context of the findings and outcome from the project, as well as targeted consultation with stakeholder, review the planetary protection regulation process and the current planetary protection guidelines and categories related to of outer solar system bodies, including small solar system bodies, and suggest improvements to COSPAR.
PPOSS Objective 4

Review of the international outer solar system planetary protection regulation structure, process and categorisation, suggest improvements

- Policy/Regulation Recommendation -

- Review and analysis of current outer solar system protection policy, including small solar system bodies, and suggest improvements to COSPAR.
Dissemination of knowledge

Facilitate the dissemination of knowledge related to planetary protection as well as of the outcome of the project to a wider international audience through seminars. Develop and maintain the project website and a repository for planetary protection-related documentation.
PPOSS Objective 5

**Dissemination of knowledge**

Facilitate the dissemination of knowledge related to planetary protection as well as of the outcome of the project to a wider international audience through seminars. Develop and maintain the project website and a repository for planetary protection-related documentation.

- Website, Seminars -