New Planetary Protection Considerations for Icy Worlds

November 2023 OPAG Meeting

Ocean Worlds / Icy Bodies Subcommittee (Chair: Peter Doran)

Presented by Alex Hayes, Cornell University

*NOTE: Material presented herein is preliminary and under review. Considerations discussed in this presentation are suggestions and DO NOT represent current COSPAR Planetary Protection Policy.*
From the COSPAR Policy on Planetary Protection (Fisk et al. 2021):

“The conduct of scientific investigations of possible extra-terrestrial life forms, pre-cursors, and remnants must not be jeopardized. In addition, the Earth must be protected from the potential hazard posed by extra-terrestrial matter carried by a spacecraft returning from an inter-planetary mission.”

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Protection Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I</td>
<td>Missions to targets not of direct interest for understanding the chemical</td>
<td>No protection warranted</td>
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<tr>
<td></td>
<td>evolution or origin of life.</td>
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<tr>
<td>Category II</td>
<td>Missions to targets with significant interest for evolution/origin of life,</td>
<td>Documentation only</td>
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<td></td>
<td>but where there is only a remote chance that contamination would compromise</td>
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<td></td>
<td>future investigations</td>
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<td>Category III</td>
<td>Missions to targets with significant interest for evolution/origin of life,</td>
<td>Documentation and implementation</td>
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<td>but where there is a significant change that contamination would compromise</td>
<td>procedures (e.g., trajectory biasing,</td>
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<td></td>
<td>future investigations</td>
<td>bioburden reduction, cleanroom</td>
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<td></td>
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<td>assembly)</td>
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<td>Category IV</td>
<td>Missions to targets with significant interest for evolution/origin of life,</td>
<td>Detailed Documentation and more stringent</td>
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<td>but where there is a significant change that contamination would compromise</td>
<td>implementation procedures (e.g.,</td>
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<td>future investigations</td>
<td>sterilization)</td>
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<tr>
<td>Category V</td>
<td>All Earth-return missions (can be unrestricted or restricted)</td>
<td>Highest concern for restricted Earth-return</td>
</tr>
</tbody>
</table>

- Category I: (flyby/orbiter) [no contact]
- Category III: (probe/lander) [direct contact]
Recent discussions within the COSPAR Panel on Planetary Protection have led to several suggestions regarding planetary protection considerations for Icy Worlds:

1) Establish a new definition of Icy Worlds for use in Planetary Protection: “Icy Worlds in our Solar System are defined as all bodies with a crustal composition believed to be greater than 50% water ice by volume that have enough mass to assume a nearly round shape”

2) Establish indices for the lower limits of Earth life with regards to water activity (LLAw) and temperature (LLT) and apply them into all areas of the COSPAR Planetary Protection Policy (currently 0.5 and -28ºC, respectively).

3) Establish LLT as a parameter to assign categorization for Icy Worlds missions (subject to 1000-year period of biological exploration).

4) Have all missions consider the possibility of impact.

5) Restructure or remove Category II* from the policy.

6) Establish any sample return from an Icy World as Category V restricted Earth return.
New Icy World PP recommendations are detailed in a manuscript that has been submitted to Life Sciences in Space Research and will be discussed during the open session of the the upcoming COSPAR PPP Meeting on Dec. 6, 2023 ([https://cosparhq.cnes.fr/scientific-structure/panels/panel-on-planetary-protection-ppp/](https://cosparhq.cnes.fr/scientific-structure/panels/panel-on-planetary-protection-ppp/))

*Note: These are currently only suggestions, NOT official PP Policy*
Recommended framework for Icy World mission PP categorization:

(Access = $>10^{-4}$ Probability of introducing a single viable terrestrial organism)

- **Orbiter**
  - Access to only temperatures below LLT in 1000 years
  - Access to temperatures above LLT at any time in 1000 years
  - Category III

- **Lander**
  - Access to only temperatures below LLT in 1000 years
  - Access to temperatures above LLT at any time in 1000 years
  - Category IV

**LLT = Lower Limit for Temperature (currently -28°C)**
Category II*
(Titan, Ganymede, Triton, Pluto-Charon, and Kuiper-belt objects > \(\frac{1}{2}\) the size of Pluto)

Current Policy:
The mission-specific assignment of these bodies to Category II must be supported by an analysis of the “remote” potential for contamination of the liquid-water environments that may exist beneath their surfaces (a probability of introducing a single viable terrestrial organism of < \(1 \times 10^{-4}\)), addressing both the existence of such environments and the prospects of accessing them.” (Fisk et al., 2021)

Recommendation:
A unified Icy World mission categorization, based on the LLT, would make Category II* largely redundant. Under this new Icy Worlds categorization, all Icy Worlds, not just those listed under II*, would undergo the analysis required by II* in the current policy (Fisk et al., 2021)

Potential Issue: Kuiper-belt objects > \(\frac{1}{2}\) the size of Pluto that do not meet Icy World Definition
5. Environmental conditions for replication

Given current understanding, the physical environmental parameters in terms of water activity and temperature thresholds that must be satisfied at the same time to allow the replication of terrestrial microorganisms are (Ref: [11], [12]):

- Lower limit for water activity: 0.5
- Lower limit for temperature: -28°C


It’s all about temperature and connectivity

• Europa (Jupiter) clear evidence of connection on some timescale to fluids beneath
  \( T_{\text{surf}}=-143^\circ \text{C} \) (midday at equator, colder toward poles / other times)

• Enceladus (Saturn) plumes indicating connection
  \( T_{\text{surf}}=-193^\circ \text{C} \) (midday at equator, colder toward poles / other times)

• Ganymede (Jupiter) internal ocean \(~3 \times\) larger than Europa, but lacks clear evidence of a connection
  \( T_{\text{surf}}=-113^\circ \text{C} \) (midday at equator, colder toward poles / other times)

• Titan (Saturn) internal ammonia-rich water but at \(~-100^\circ \text{C}\). Possible connection, but perhaps only one-way
  \( T_{\text{surf}}=-179^\circ \text{C} \)

• Calisto (Jupiter), possible deep (100 km) subsurface ocean.
  \( T_{\text{surf}}=-110^\circ \text{C} \) (midday at equator, colder toward poles / other times)

• Triton (Neptune), may (?) have an internal ocean about 100-150 km ice shell
  \( T_{\text{surf}}=-235^\circ \text{C} \)

• Ceres, likely lacks an internal liquid ocean but brines flow through the outer mantle and reach surface
  \( T_{\text{surf}}=-38^\circ \text{C} \) (midday at equator, colder toward poles / other times)
Europa and Enceladus are too cold in the top several kms to support life. Missions need to establish reasonable estimates for depth to -28°C and show less than $1 \times 10^{-4}$ chance of contamination to that depth in 1000 years.
“The shallowest depth which sustains a temperature of -28°C is 4 km beneath the surface of a 5 km thick Enceladean ice shell when we assume the maximum surface temperature (solid red line of right plot)”

Courtesy Britney Schmidt and Jacob Buffo