

PROPOSED NEW COSPAR PLANETARY PROTECTION POLICY GUIDELINES FOR MISSIONS TO ICY WORLDS: P.T. Doran¹, A. Hayes², O. Grasset³, A. Coustenis⁴, O. Prieto-Ballesteros⁵, Britney Schmidt², Jacob Buffo⁶ and the COSPAR Panel on Planetary Protection, ¹Department of Geology and Geophysics, Louisiana State University, Baton Rouge, Louisiana, pdoran@lsu.edu, ²Cornell University, Ithaca, NY, ³Nantes Université, Nantes, France, ⁴LESIA, Paris Observatory, PSL University, CNRS, Paris University, 92195 Meudon Cedex, France, ⁵Centro de Astrobiología (CAB), CSIC-INTA, 28850 Torrejón de Ardoz, Madrid, Spain, ⁶Thayer School of Engineering, Dartmouth College, Hanover, NH, USA.

Introduction: The detection of living organisms on Icy Worlds of the outer Solar System would have a profound impact on both science and society. Whether extant or extinct, such a discovery would provide important insights into our understanding of biological and/or biochemical processes as well as the possibility for multiple origins of life. Today, we still lack a well-constrained understanding of detailed conditions that lead to, or prohibit, the origin of life. Regardless, observations by space missions and ground-based telescopes have demonstrated the presence of habitable conditions on some outer solar system bodies, including the moons of Jupiter and Saturn. It is therefore, both important and timely to review and update planetary protection policies for exploring the Icy Worlds.

Herein, we propose an update of the Committee on Space Research (COSPAR) Planetary Protection policy (hereafter “the Policy”) concerning Icy Worlds that centers around the low-temperature limit for life as we know it on Earth.

The COSPAR Policy and Panel on Planetary Protection:

The Panel on Planetary Protection (PPP) was established by COSPAR in 1999, with the responsibility of consolidating, maintaining, and updating the COSPAR Policy, as well as ensuring its dissemination to relevant stakeholders [1]. The Panel currently consists of 24 members, including an equal number of representatives from national space agencies (such as China, France, Germany, the United Kingdom, India, Italy, Japan, the Russian Federation, Canada, the United Arab Emirates, the United States, and the European Space Agency) and thematic experts from the international scientific community. Additionally, the Panel welcomes ex-officio members from the National Academies of Science, Engineering and Medicine (NASEM), the United Nations Office of Outer Space Affairs (UNOOSA), and the COSPAR Committee on Industrial Relations, as well as COSPAR Leadership who contribute to the Panel’s activities. The Panel also invites participation from other stakeholders, including the private sector and industry. Information about the Panel and related documents can be found on the COSPAR website [2].

To ensure the COSPAR Policy is up to date and useful for space missions, the Panel conducts regular reviews of scientific data through studies, community

consultations, workshops, technical meetings, and discussions at scientific and engineering congresses dedicated to space exploration [1]. The Panel evaluates new information, formulates need for any updates to the Policy, and provides recommendations to the COSPAR Bureau and Council for validation of potential policy and requirement modifications.

Planetary Protection of Icy Worlds: In 2022 a subcommittee of the PPP was established to review guidelines regarding Icy Worlds and make proposals for updates if appropriate. The committee immediately saw a need to shore up the language, and just use the term Icy Worlds (as opposed to e.g. Icy Moons or Ocean Worlds) in the Policy. This is because not all Icy Worlds that are of concern to planetary protection are moons, and a body does not need an ocean to be of concern for planetary protection. For these reasons, we propose the following definition for an Icy World:

Icy Worlds in our Solar System are defined as all bodies with an outermost layer that is believed to be greater than 50% water ice by volume and have enough mass to assume a nearly round shape.

A threshold of 50% was chosen because bodies of the outer Solar System are half ice/rock and, if they have a round shape, differentiation is going to make the outermost layer >50% water ice by volume (water ice in this definition is considered to encompass both amorphous ice and clathrate phases). The above definition includes dwarf planets like Pluto, but excludes small bodies including comets, trojans, irregular moons, and Trans-Neptunian Objects (TNOs) including Centaurs and smaller Kuiper Belt Objects (KBOs). While Ceres’ surface composition likely does not meet the >50% water ice requirement to be considered by the above definition, it was included in our considerations as it shares many of the characteristics and exploration objectives of the other Ocean Worlds (that are also Icy Worlds) [3].

The committee also recognized the utility of the lower limits of life for temperature and water activity that were initially developed for defining Mars Special Regions and were recently added to the policy for general use in the Solar System. The subcommittee proposed to make indices from these limits. LLT is the lower temperature limit (currently -28°C) for and

LLAw is the lower water activity limit (currently 0.5) for replication. For ice, LLaW is difficult to define and so we make the conservative assumption that on Icy Worlds, conditions are always above this limit ($A_w > LLa_w$). This allows to just focus on temperature as the environmental trigger for concern about forward contamination (vs. water which is currently in the Policy). With this framework, an Icy World (not just Europa and Enceladus) categorization that is based on the modeled depth to the LLT and the likelihood of a connection from the surface to that depth is proposed. For an orbiting mission, if the probability of a single viable microbe inadvertently reaching a depth with temperatures \geq LLT is less than 10^{-4} in 1000 years, that mission would be classified as Category II. Other examples of how this categorization would work are shown in the Figure 1. Note that the use of a PBE (Period of Biological Exploration) of 1000 years for all Icy Worlds (not just Europa and Enceladus) is used, as was intended by the National Research Council [4]. All missions should consider the possibility of impact. Transient thermal anomalies caused by impact would be acceptable so long as there is less than 10^{-4} probability of a single microbe reaching regions with an ambient temperature \geq LLT in the PBE.

Note that a unified Icy World mission categorization, based on the LLT, might make Category II* largely redundant in the Policy. This is because under this new Icy Worlds categorization, all Icy Worlds, not just those listed under II*, would undergo the analysis required by II* currently [5]. This means that all the named Icy Worlds listed as Category II* (Ganymede, Titan, Triton, and Pluto/Charon) would no longer require this designation as they will be covered by the new Icy Worlds categorization. That would leave the only object designated with an asterisk (*) in Category II being “Kuiper-belt objects $> \frac{1}{2}$ the size of Pluto”. It is possible that these objects are also captured by our Icy World definition, but not certain. To address this, the Panel proposes that we assume the larger KBOs will be sufficiently captured by our Icy World definition and leave KBOs in Category II only as “KBO’s that cannot be classified as Icy Worlds”. But, due to knowledge gaps, further discussion and community input is required before final decisions.

Another area that needs more discussion and consensus is sample return from Icy Worlds. The limits of extant life survivability that may exist on an Icy World is unknowable prior to the discovery of such life. Therefore, a conservative approach demands that any sample return from an Icy World should be categorized as restricted Earth return. It is also unknown how long Icy World biota can remain

dormant but viable preserved in ice. Furthermore, all Icy Worlds would almost certainly be classified as restricted Earth return using the 6 questions in Section 11.2 of the current policy [5]. Sample return from Icy Worlds will be a topic of further discussion.

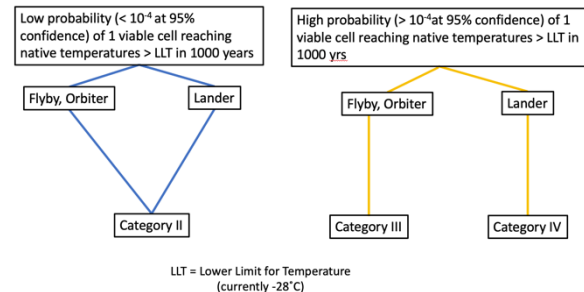


Figure 1: Proposed decision tree for new unified Icy World Categorization.

These are recommendations/findings only and not specific policy changes. In the next steps, these findings will be discussed and promoted at relevant planetary meetings and at the COSPAR Panel on Planetary Protection meetings. Specific policy changes can be developed after that for validation by the COSPAR Bureau. The Panel will continue to work on developing sensible and scientifically rigorous guidelines for exploration of the Solar System objects in consultation with the scientific community, different national and international space agencies, scientists and engineers, and other stakeholders (e.g., the private sector and industry). In particular, our study of Icy Worlds has pointed at knowledge gaps that require further investigations and scientific input.

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