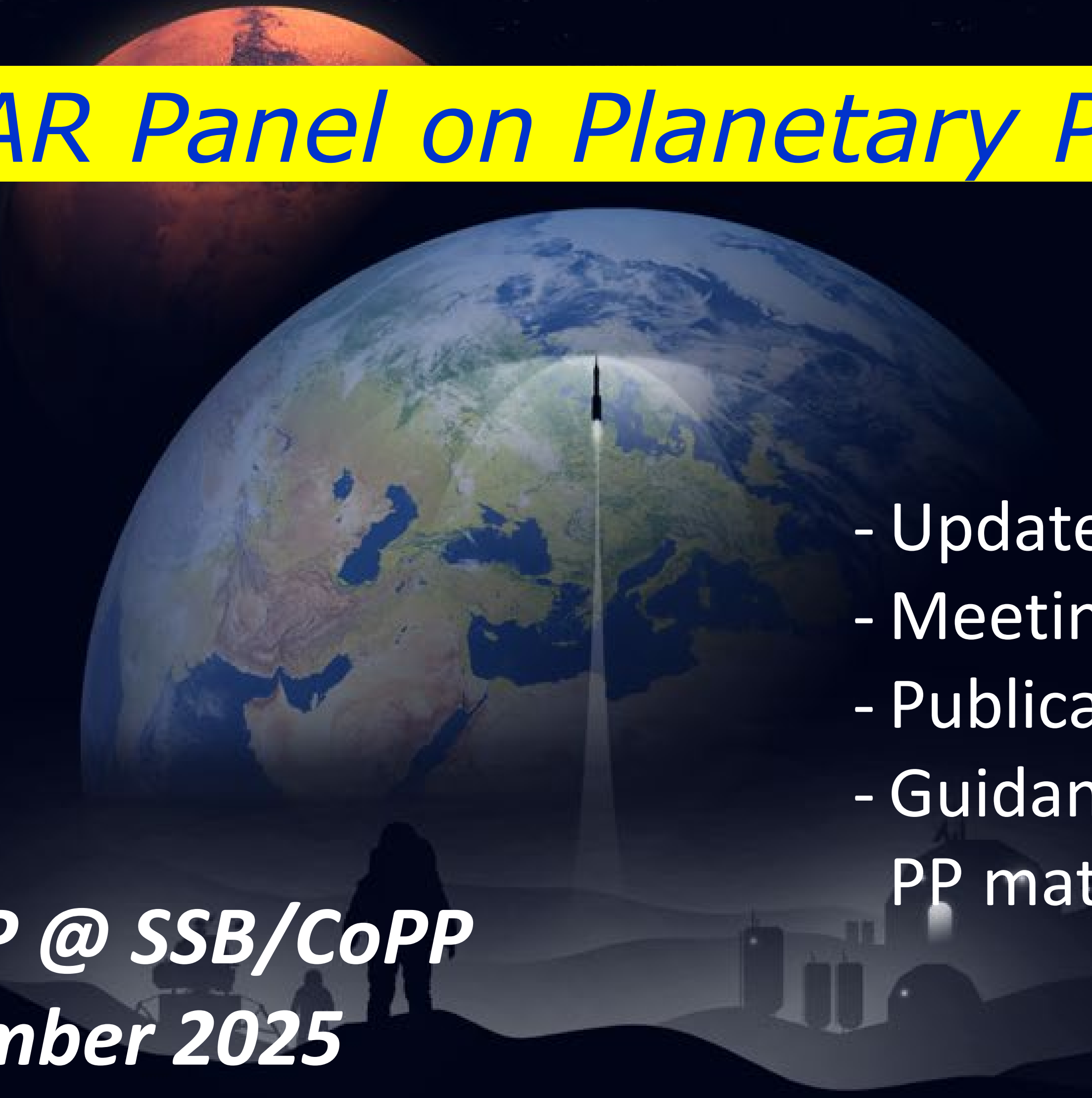
The COSPAR Panel on Planetary Protection

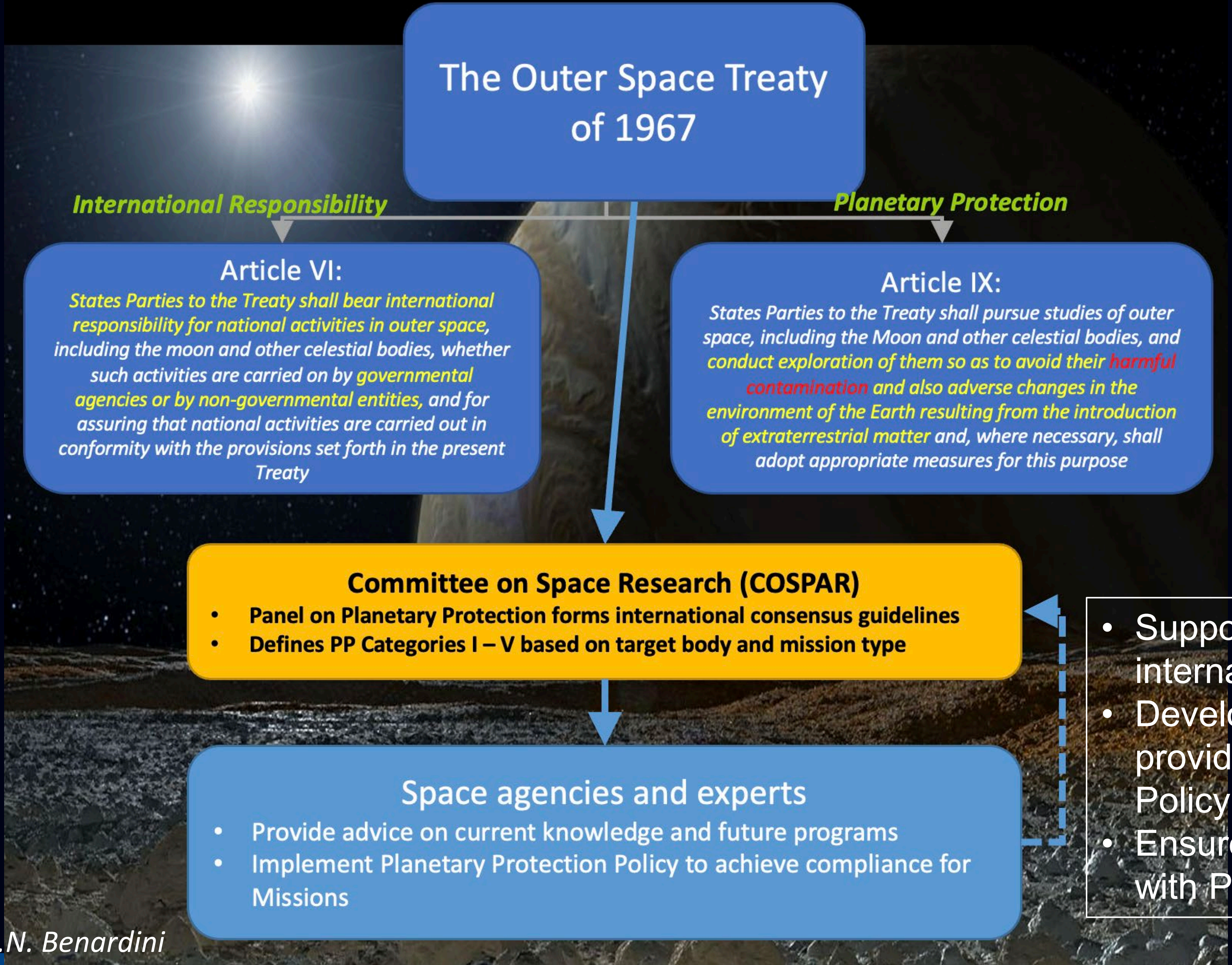


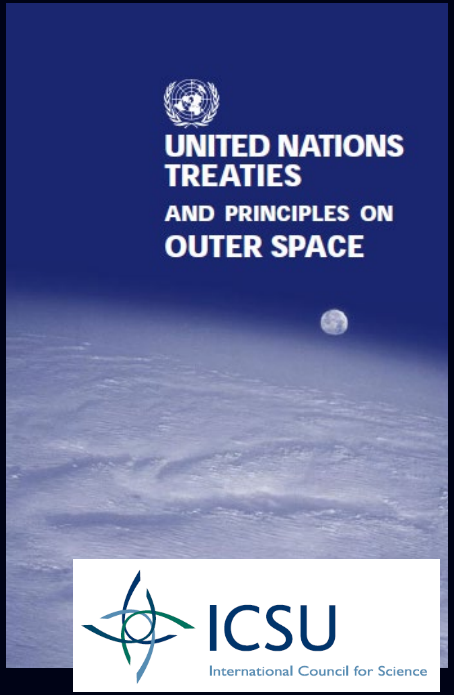
- Update of the Policy
- Meetings
- Publications/communications
- Guidance to space missions on PP matters

COSPAR PPP @ SSB/CoPP
10 December 2025

https://cosparhq.cnes.fr/scientific-structure/ppp

Framework for planetary protection





- Support the science-based international consensus process
- Develops new guidelines and provides significant input to COSPAR Policy (via the PPP) for updates
- Ensure implementation in compliance with PP Policy

Credit: J.N. Benardini

COSPAR planetary protection Panel & Policy

A special case among the Commissions and Panels in the COSPAR structure is the Panel of Planetary Protection (PPP) which serves an important function for space agencies pursuing the exploration of the planets. The primary objective of the COSPAR PPP is to develop, maintain, and promote the COSPAR policy and associated requirements for the reference of spacefaring nations and to guide compliance with the Outer Space Treaty ratified today by 114 nations, to protect against the harmful effects of forward and backward contamination, i. e.

- The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized.
- In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission.

- *This policy must be based upon the most current, peer-reviewed scientific knowledge, and should enable the exploration of the solar system, not prohibit it. The Panel has several meetings and invites all stakeholders including the private sector.*

- *It is not the purpose of the Panel to specify the means by which adherence to the COSPAR Planetary Protection Policy and associated guidelines is achieved; this is reserved to the engineering judgment of the organization responsible for the planetary mission, subject to certification of compliance with the COSPAR planetary protection requirements by the national or international authority responsible for compliance with the Outer Space Treaty.*

COSPAR Panel on Planetary Protection Members

Chair: Athena **Coustenis** (Paris Observ., FR; planetary sciences, astrobiology)

Vice-Chairs: Niklas **Hedman** (space law and policy) &

Peter **Doran** (LA State Univ., USA; Hydrogeology, Extreme Environments)

12 members appointed by space agencies		11 experts + 3 ex-officio	
Canada/CSA	Tim Haltigin (planetary sciences)	France	Olivier Grasset (geodynamics, planetology)
Germany/DLR	Petra Rettberg (microbiology, astrobiology)	USA	Alex Hayes (planetology)
China/CNSA	Jing Peng (engineering)	Russia	Vyacheslav K. Ilyin (microbiology, medicine)
ESA	Silvio Sinibaldi (astrobiology)	Spain	Maria-Paz Zorzano Meier (astrobiology, biophysics)
France/CNES	Christian Mustin (astrobiology)	France	François Raulin (chemistry, planetology)
India/ISRO	Anand Jain (engineering science)	Japan	Yohey Suzuki (microbiology)
Italy/ASI	Eleonora Ammannito (planetologist)	Canada	Lyle Whyte (Cold regions microbiology)
Japan/JAXA-ISAS	Masaki Fujimoto (space plasma physics)	China	Kanyan Xu (microbiology, biochemistry)
Russia/Roscosmos	Natalia Khamidullina (Radiation)	Russia	Maxim Zaitsev (astrochem, organic chem.)
UAE	Omar Al Shehhi (engineering)	UAE	Jeremy Teo (mechanical and bio engin.)
UK/UKSA	Karen Olsson-Francis (astrob., microbiology)	UK	Mark Sephton (astrobiob., org. geochem.)
USA/NASA	Elaine Seasly (contamination , engineering)	COSPAR CIR Ex-officio	John Reed
NASEM Ex-officio	Aru Mozhi Aeron., Astron. Physics, & Space Science Director	UNOOSA Ex-officio	Michael Newman

Invited commercial

Blue Origin

SpaceX

AIRBUS

ThalesAlenia Space

OHB

And more

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Working sessions of the COSPAR Panel on Planetary Protection

The Panel provides, through workshops and meetings at COSPAR Assemblies and elsewhere, an international forum for the exchange of information on the best practices for adhering to the COSPAR planetary protection requirements. The PPP has strong ties with other relevant bodies world-wide (e.g. NASEM SSB/CoPP). Through COSPAR GAs, focused meetings with Open Sessions and publications the Panel informs the international community, including holding an active dialogue also with the private sector.

Planetary protection categories

The different planetary protection categories (I-V) reflect the level of interest and concern that contamination can compromise future investigations or the safety of the Earth; the categories and associated requirements depend on the target body and mission type combinations

Category I: All types of mission to a target body which is not of direct interest for understanding the process of chemical evolution or the origin of life; *Undifferentiated, metamorphosed **asteroids**; others TBD*

Category II: All types of missions (gravity assist, orbiter, lander) to a target body where there is significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote[1] chance that contamination carried by a spacecraft could compromise future investigations; ***Venus**; **Moon (IIa and Iib with organic inventory only for landed missions at the poles and in PSRs)** Comets; Carbonaceous Chondrite Asteroids; Jupiter; Saturn; Uranus; Neptune; Ganymede†; Titan†; Triton†; Pluto/Charon†; Ceres; Kuiper-Belt Objects > 1/2 the size of Pluto†; Kuiper-Belt Objects < 1/2 the size of Pluto; others TBD*

Category III: Flyby (i.e. gravity assist) and orbiter missions to a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant[2] chance of contamination which could compromise future investigations; ***Mars; Europa, Enceladus and other icy worlds; others TBD***

Category IV: Lander (and potentially orbiter) missions to a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant[2] chance of contamination which could compromise future investigations. 3 subcategories exist (IVa,b,c) depending on instruments, science investigations, special regions etc.; ***Mars**; **Europa, Enceladus and other icy worlds**, others TBD*

Category V: All Earth return: 2 subcategories - unrestricted return for solar system bodies deemed by scientific opinion to have no indigenous life forms (***e.g. Martian Moons***) and restricted return for all others

[1]*Implies the absence of environments where terrestrial organisms could survive and replicate, or a very low likelihood of transfer to environments where terrestrial organisms could survive and replicate*

[2]*Implies the presence of environments where terrestrial organisms could survive and replicate, and some likelihood of transfer to those places by a plausible mechanism*

Planetary protection categories

The different planetary protection categories (I-V) reflect the level of interest and concern that contamination can compromise future investigations or the safety of the Earth; the categories and associated requirements depend on the target body and mission type combinations

From the NASA Planetary Protection Handbook

		Planetary Protection Mission Category	Mission Type	Target Body Type: Potential for Indigenous Life	Target Body Type: Significance of Contamination: Understanding the process of chemical evolution or origin of life	Target Body Type: Significance of Contamination: Chance that contamination could compromise future investigations
Increasing Biological Contamination Risk	Forward Planetary Protection	Category I	All outbound types	None	Not of direct interest	None
Increasing Biological Contamination Risk	Forward Planetary Protection	Category II	All outbound types	None	Significant	Remote
Increasing Biological Contamination Risk	Forward Planetary Protection	Category III	No direct contact: Flyby, orbiter, gravity assist	Possible	Significant	Significant
Increasing Biological Contamination Risk	Forward Planetary Protection	Category IV	Direct contact: Lander/probe	Possible	Significant	Significant
Increasing Biological Contamination Risk	Backward Planetary Protection	Category V(r) - Restricted	Earth return	Possible	Significant	Significant
	Backward Planetary Protection	Category V(u) - Unrestricted	Earth return	None	--	--

Overview of COSPAR Panel on Planetary Protection Recent activities

Updated planetary protection Policy for the Moon

9 April 2021: COSPAR Panel on Planetary Protection Meeting issuing new requirements for lunar exploration

Orbiter and fly-by missions to the Moon: *Category II*. There is no need to provide an organic inventory

Lander missions to the Moon :

- *Category IIa*. All missions to the surface of the Moon whose nominal mission profile does not access areas defined in Category IIb shall provide the planetary protection documentation and an organic inventory limited to organic products that may be released into the lunar environment by the propulsion system (relaxed requirements),
- *Category IIb*. All missions to the surface of the Moon whose nominal profile access Permanently Shadowed Regions (PSRs) and the lunar poles, in particular latitudes south of 79°S and north of 86°N shall provide the planetary protection documentation and full organic inventory

Category II: All types of missions (gravity assist, orbiter, lander) to a target body where there is significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote[1] chance that contamination carried by a spacecraft could compromise future investigations

The requirements are for simple documentation only.

*Updated COSPAR Policy published in Space Res. Today **211**, 14-20 (Aug. 2021);*
https://doi.org/10.1016/j.srt.2021.07.009.

Small bodies and Venus

- ❑ ***No change in Planetary Protection category for small bodies***

  PPP took the 3d CoPP report into account and noted that the findings were compatible with the current policy. After thorough considerations and discussion by the Panel experts, it was decided that there was no need currently to change anything in the Policy as concerns small bodies.

Coustenis et al., 2023. Front. Astron. Space Sci. 10:1172546.

Check for updates

OPEN ACCESS

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Planetary protection: an international concern and responsibility

Athena Coustenis[1]*, Niklas Hedman[2], Peter T. Doran[3], Omar Al Shehhi[4], Eleonora Ammannito[5], Masaki Fujimoto[6], Olivier Grasset[7], Frank Groen[8], Alexander G. Hayes[9], Vyacheslav Ilyin[10], K. Praveen Kumar[11], Caroline-Emmanuelle Morisset[12], Christian Mustin[13], Karen Olsson-Francis[14], Jing Peng[15], Olga Prieto-Ballesteros[16], Francois Raulin[17], Petra Rettberg[18], Silvio Sinibaldi[19], Yohey Suzuki[20], Kanyan Xu[21] and Maxim Zaitsev[22]

Zorzano Meier et al., 2023. LSSR 37, 18-24

Contents lists available at ScienceDirect

Life Sciences in Space Research

journal homepage: www.elsevier.com/locate/lssr

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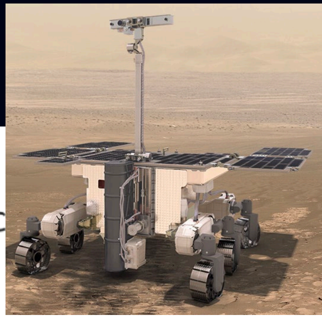
The COSPAR planetary protection requirements for space missions to Venus

María Paz Zorzano[a,*], Karen Olsson-Francis[b], Peter T. Doran[c], Petra Rettberg[d], Athena Coustenis[e], Vyacheslav Ilyin[f], Francois Raulin[g], Omar Al Shehhi[h], Frank Groen[i], Olivier Grasset[j], Akiko Nakamura[k], Olga Prieto Ballesteros[a], Silvio Sinibaldi[l], Yohey Suzuki[m], Praveen Kumar[n], Gerhard Kminek[o], Niklas Hedman[p], Masaki Fujimoto[q], Maxim Zaitsev[r], Alex Hayes[s], Jing Peng[t], Eleonora Ammannito[u], Christian Mustin[v], Kanyan Xu[w]

- ❑ ***No change in the Planetary Protection category for Venus*** : *the environmental conditions within the Venusian clouds are orders of magnitude drier and more acidic than the tolerated survival limits of any known terrestrial extremophile organism. Because of this, future orbital, landed or entry probe missions to Venus do not require extra planetary protection measures.*

Knowledge gaps for Mars exploration



- **Robotic exploration of Mars:** *there are still several knowledge gaps that need to be addressed before they can be directly applied to accommodate the interest of the user. In brief, these knowledge gaps fall within three main themes, all of which will benefit from more measurements by space missions and ground-based observations: Biocidal effects, contamination transport model and Mars environmental conditions*

Life Sciences in Space Researc

Olsson-Francis et al., 2023. LSSR 36, 27-35

The COSPAR Planetary Protection Policy for robotic missions to Mars: A review of current scientific knowledge and future perspectives

Karen Olsson-Francis [a], Peter T. Doran [b], Vyacheslav Ilyin [c], Francois Raulin [d], Petra Rettberg [e], Gerhard Kminek [f], María-Paz Zorzano Mier [g], Athena Coustenis [h], Niklas Hedman [i], Omar Al Shehhi [j], Eleonora Ammannito [k], James Bernardini [l], Masaki Fujimoto [m], Olivier Grasset [n], Frank Groen [l], Alex Hayes [o], Sarah Gallagher [p], Praveen Kumar K [q], Christian Mustin [r], Akiko Nakamura [s]...Maxim Zaitsev [v]

ASTROBIOLOGY
Volume 24, Number 3, 2024

DOI: 10.1089/ast.2023.0092

Planetary Protection Knowledge Gap Closure Enabling Crewed Missions to Mars

James A. Spry,[1] Bette Siegel,[2] Corien Bakermans,[3] David W. Beaty,[4] Mary-Sue Bell,[5] James N. Benardini,[2] Rosalba Bonaccorsi,[1,6] Sarah L. Castro-Wallace,[5] David A. Coil,[7] Athena Coustenis,[8] Peter T. Doran,[9] Lori Fenton,[1] David P. Fidler,[10] Brian Glass,[6] Stephen J. Hoffman,[11] Fathi Karouia,[6] Joel S. Levine,[12] Mark L. Lupisella,[13] Javier Martin-Torres,[14,15] Rakesh Mogul,[16] Karen Olsson-Francis,[17] Sandra Ortega-Ugalde,[18] Manish R. Patel,[17] David A. Pearce,[19] Margaret S. Race,[1] Aaron B. Regberg,[5] Petra Rettberg,[20] John D. Rummel,[21] Kevin Y. Sato,[2] Andrew C. Schuerger,[22] Elliot Sefton-Nash,[18] Matthew Sharkey,[23] Nitin K. Singh,[4] Silvio Sinibaldi,[18] Perry Stabekis,[1] Carol R. Stoker,[6] Kasthuri J. Venkateswaran,[4] Robert R. Zimmerman,[24] and Maria-Paz Zorzano-Mier[25]

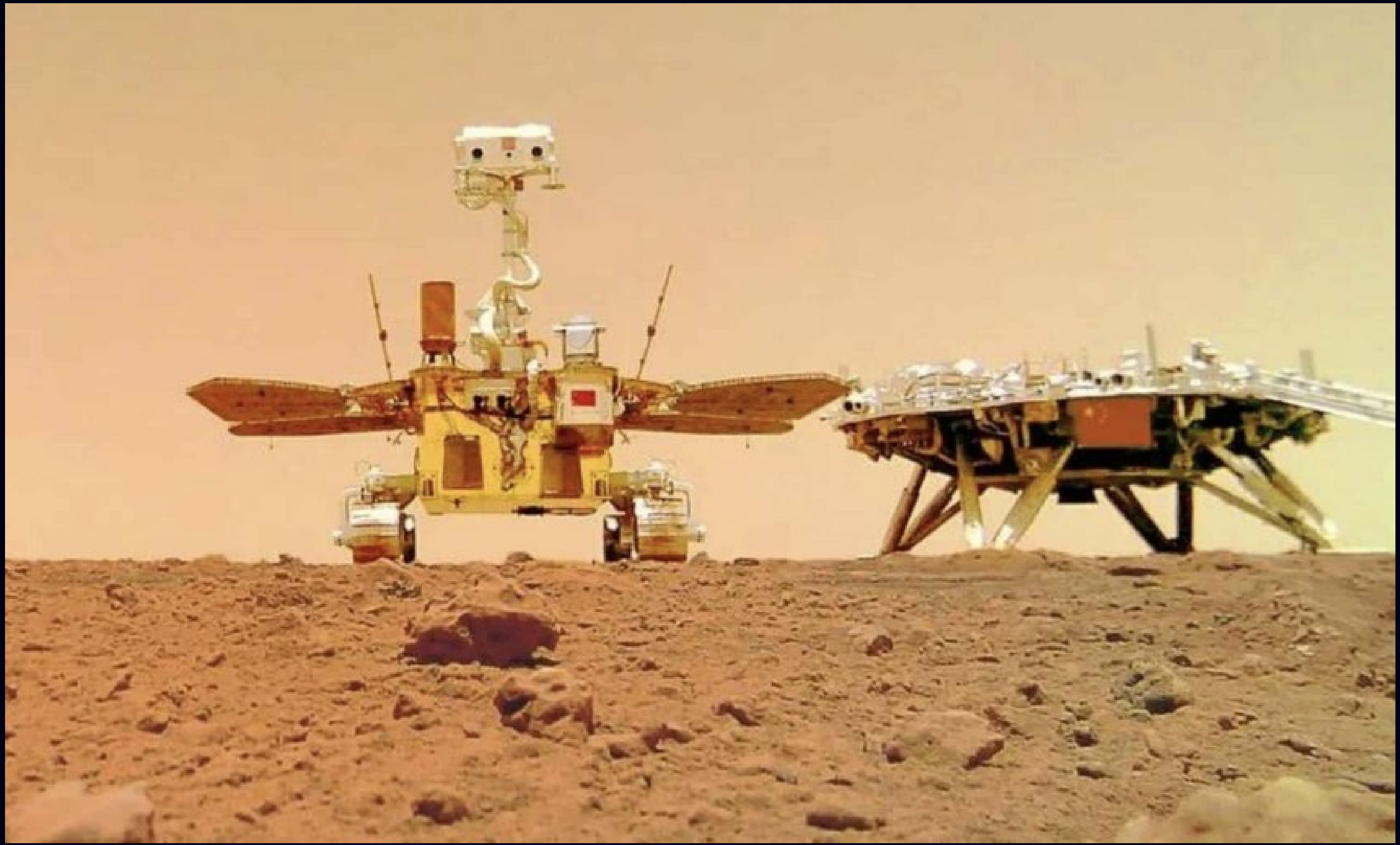
Spry et al. (2024. Astrobiology. 24(3):230-274.

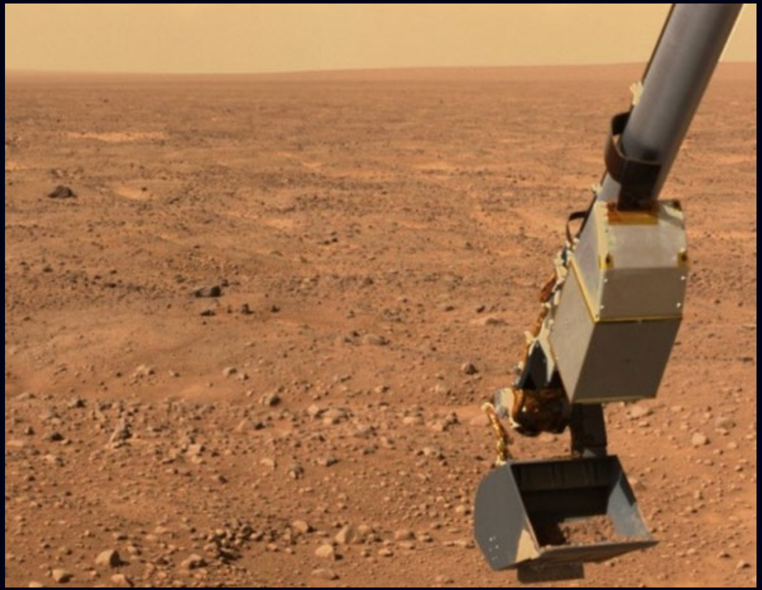
- **Gap closure for crewed missions to Mars**: *A report was issued after the June 2022 COSPAR-NASA Meeting on "Planetary Protection Knowledge Gaps for Crewed Mars Missions" and represented the completion of the series. This report aims to identify, refine, and prioritize the knowledge gaps that are needed to be addressed for planetary protection for crewed missions to Mars, and describes where and how needed data can be obtained.*

CAST : Tianwen-3 mission for Mars sample return

中国行星探测
Zhōngguó Xíngxīng Tàncè

中国行星探测
PEC
Emblem of Planetary Exploration of China
Reaching for the Planets





Two spacecraft (an orbiter/Earth-returner and a lander/ascent-vehicle) via two separate launches in 2028-2030 to Mars. Together, the two spacecraft will seek to obtain samples of Martian rocks and soil and then return the cached samples to Earth. The mission architecture is similar to MSR.

CAST has informed the PPP that all the PP measures applied to this mission are following COSPAR Policy guidelines

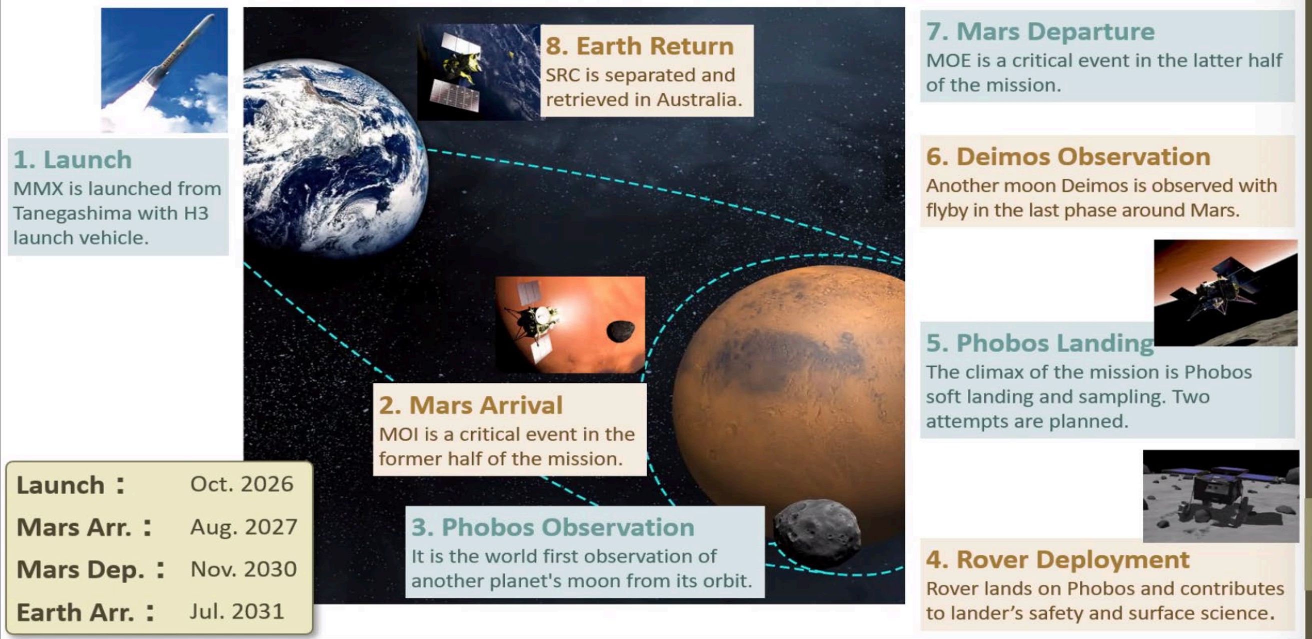
JAXA: Martian Moons eXploration

Three Major Items of MMX Mission Value

MMX is a **unique Martian sphere exploration** mission lead by Japan. It sets in its view of Martian moons, Martian life, and future crewed exploration in one mission.

Mission Profile

The mission is targeting the launch in 2026. A five-year trip is planned to retrieve samples back to Earth within three years of staying around Mars. The mission is full of critical and attractive events.



COSPAR was involved throughout the multi-year-long process and at the end assigned a planetary protection category specifically for the MMX mission (outbound Cat III and inbound Cat V: unrestricted Earth return)

"Planetary protection: New aspects of policy and requirements", 2019. ***Life Sci. Space Res.*** *23*

JAXA's MMX mission PP categorisation
Sample return from Phobos

COSPAR
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→In 2019 ESA and JAXA studied sample return missions from Phobos and Deimos

→To support a categorization, ESA initiated an activity with a science consortium to evaluate the level of assurance that no unsterilized martian material naturally transferred to Phobos (or Deimos) is accessible to a Phobos (or Deimos) sample return mission. NASA supported the activity from the very beginning providing test materials and expert advice, followed by JAXA with their own experimental and modelling work supporting the overall assessment

→The ESA-JAXA-NASA coordinated activities finished with an independent review by the NAS and the European Science Foundation presented to the ESA Planetary Working Group (PPWG) and to COSPAR

Conclusions based on the studies supported by ESA-JAXA-NASA :

1. Microbial contamination probability of collected samples from the Martian moons can be reduced to less than 10^{-6} (REQ10) by choosing appropriate sampling approaches. For example,

   a. To collect 100-g samples with a restriction of boring depth <5cm.

   b. To avoid recent craters when samples are collected.

   c. To limit the collected mass of samples below 30g (no restriction on sampling depth).

   d. Flight hardware assembly in ISO Level 8 cleanrooms.

2. Martian meteorites transported from Mars to Earth in the past 1 Myr have microbial contamination probability much higher by orders of magnitude (10^3 or more) than that of 100-g samples taken from the Martian moons. This means that natural influx equivalent to samples from Martian moons is continuously and frequently transported to the surface of the Earth.

*Compliance with the JAXA's Planetary Protection Standard that fully conforms to COSPAR PP Policy. Because of the above reasons, sample return from the Martian moons can be classified as **Unrestricted Earth Return**, provided that the total mass of samples is limited within 100 kg.*

*"Planetary protection: New aspects of policy and requirements", 2019. **Life Sci. Space Res.** 23*

Categorisation of the Dragonfly mission to Titan

Review of the Planetary Protection Approach in the Project's proposal

- Per NASA's planetary protection policy (NASA Procedural Requirements 8715.24), Dragonfly needs to comply with implementation requirements that are intended to prevent the organic and biological contamination of Titan, based on the best available scientific understanding of that possibility. This is intended to address the categorization of missions promulgated by the COSPAR Policy.
- After a careful and extensive review of the current scientific literature on Titan's atmospheric and geological processes, the authors of the internal NASA report provided several ”findings" to be addressed in the proposal for the planetary protection plan for the Dragonfly mission, in order to provide a more comprehensive analysis of risks: most important risk is that bioburden could be transported from Dragonfly to habitable regions (e.g., the ocean) *Ad hoc committee led by J. Green*
- By considering various possible transport processes that could move material from Titan's surface to its subsurface liquid water ocean, the Dragonfly Proposal concluded that terrestrial microbes, if able to survive both the high temperatures experienced during entry and the profoundly cold temperatures on Titan's surface, would have a probability of less than 10^{-4} of reaching the ocean resulting in Dragonfly mission being classified in Category II.

COSPAR PPP Activities since 3 April 2025

- **COSPAR PP Workshop :**
  14-16 April, Cologne, Germany
- **Executive Meetings:** ***12 May, 17 June, 6 October 2025***
- **PPP at grand debate at EGU 2025 :**
  28 April-2 May, Vienna, Austria
- **PP talks at IAA-CAST Space flight Workshop :**
  3-5 June 2025, Xi'an, China
- **PP talks at AOGS and AGU 2025:**
  28 July-1 Aug. 2025, Singapore; 15-19 December 2025, New orleans
- **Talks/panel at IAC 2025:**
  29 Sept. -3 Oct. 2025, Sydney, Australia
- **PPP Session and talks at the COSPAR Symposium:**
  "Space Exploration 2025: A Summit on Humanity's Challenges and Celestial Solutions"
  3-7 Nov. 2025, Cyprus

The International COSPAR Panel on Planetary Protection Week: *Koln, Germany, 14-16 April 2025*

hosted by DLR and organized by P. Rettberg

The PPP at the PP Meeting in April 2025, at DLR

COSPAR PP Workshop : *14-16 April, Cologne, Germany: 2nd day*

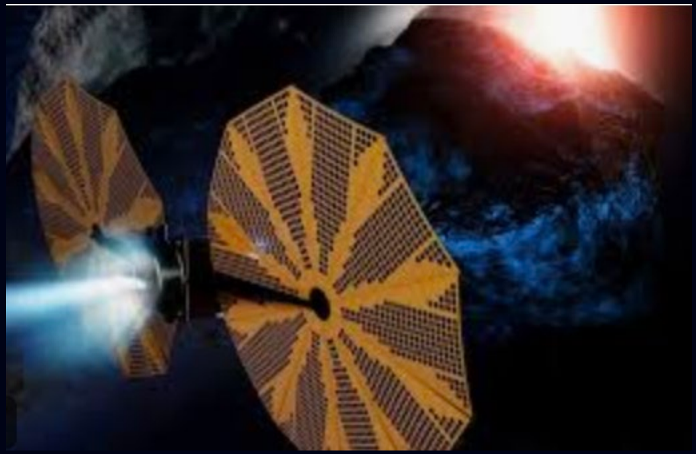
Next steps for humans to Mars	Nick Benardini
Working towards an international standard for metagenomics	Karen Olsson-Francis,Nick Benardini,Silvio Sinibaldi
COFFEE BREAK	
Extremophiles on Earth with relevance for planetary protection of Icy Worlds	Petra Rettberg
Update of ESA L4 Mission	Olivier Grasset
LUNCH	
Visit of EAC + LUNA	Jürgen Schlutz, Lothar Mies
Icy Worlds Planetary Protection Panel discussion + Q&A	*Peter Doran (Chair)*, Alex Hayes, Olivier Grasset, Olga Prieto-Ballesteros, Silvio Sinibaldi, Athena Coustenis
JUICE (Jupiter Icy Moons Explorer)	Gabriel Tobie
PP lessons learned from Europa Clipper	Ryan Hendrickson
COFFEE BREAK	
Sample return receiving and curation facilities Panel	*Christian Mustin (Chair),* Caroline Smith, Andi Harrington, Alvin Smith
American Society for Testing and Materials International PP subcommittee briefing	Betsy Pugel
Planetary Protection in the Commercial and Private sector – panel discussion + Q&A	*Niklas Hedman (Chair),* Graeme Poole (Airbus), Enrico Andrea Nistico (TAS Italy), Steve Squyres (Blue Origin), Edward “Beau” Bierhaus (Lockheed Martin)

COSPAR PP Workshop : *14-16 April, Cologne, Germany, 3d day*

Wednesday 16 April: Closed COSPAR Planetary Protection Meeting

9:00-9:30	*COFFEE*	
9:30-9:40	Introduction of topics for discussion	
9:40-10:00	Hyabusa 2 categorisation	Hajime Yano & Hyabusa 2 Team
10:00-10:20	Emirates Mission to the Asteroid belt (EMA)	Omar Al Shehhi and team
10:20-10:50	Management and mitigation of PP Knowledge Gaps between COSPAR – IMEWG –ISECG	Nick Benardini
10:50-11:20	***COFFEE BREAK***	
11:20-12:30	Discussion on Policy updates for Icy Worlds	Peter Doran
12:30-13:30	***LUNCH***	
13:30-14:00	Mars human exploration updates	Nick Benardini
14:00-14:30	Humans on the Moon	ESA, NASA, others?
14:30-14:45	Organic inventory	Silvio Sinibaldi, Karen Olsson-Francis
14:45-15:15	Other PP-related ongoing studies	All
15:15-15:30	Discussion on editorial updates for Policy	Niklas Hedman
15:30-15:45	***COFFEE BREAK***	
15:45-16:00	Membership and ToR	JCW + Peter Doran
16:00-16:15	Planning COSPAR Assembly 2026 and other symposia and publciations	Jean-Claude Worms
16:15-16:30	AOB + Concluding Remarks	Athena Coustenis & PPP Leads
16:30	*Close*	

PPP on future missions categorization to asteroids



Emirates Mission to the Asteroid Belt (EMA)

an exploration mission that will fly though the inner solar system and then investigate asteroids in the main belt between Mars and Jupiter.

- It will launch in 2028 and visit, via high-speed flyby encounters of 6 asteroids en route to a rendezvous and landing on a 7th asteroid (collaboration with LASP (Colorado).
- Goals: define origins and evolution of water-rich asteroids and assess resources potential. Planetary Flyby Gravity Assist (Venus, Earth, & Mars) and then rendezvous, descent and land on the final asteroid, Justcia.
- Due to the Mars gravity assist, EMA is proposing categorization as Category III as per COSPAR guidelines. This classification received a written approval from the COSPAR Planetary Protection Panel in April 2025

Hayabusa2 : JAXA

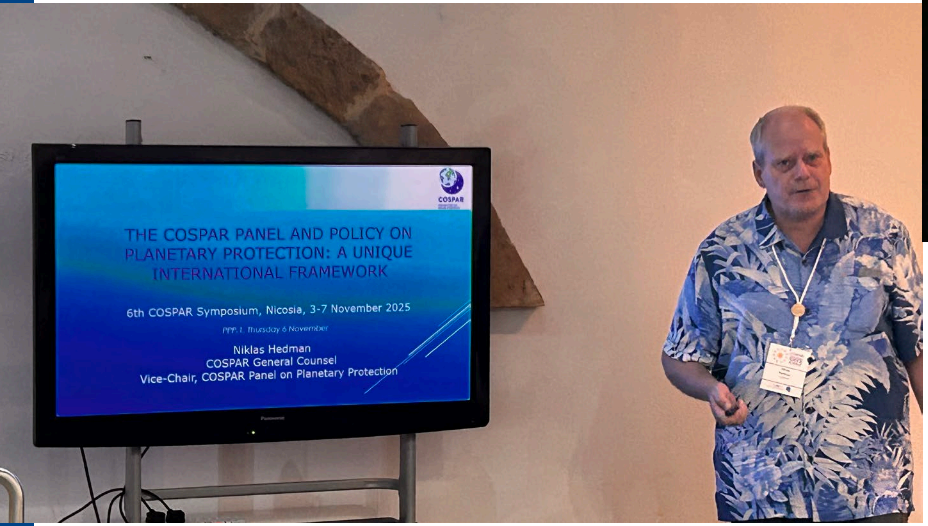
asteroid sample return mission . It was launched on 3 December 2014 and rendezvoused in space with near-Earth asteroid 162173 Ryugu on 27 June 2018.

It surveyed the asteroid for 1,5 years and took samples. It left the asteroid in November 2019 and returned the samples to Earth on 5 December 2020. It has been extended through at least 2031.

- The project manager contacted us to discuss the PP Cat proposal evaluation for the two asteroids
- Hayabusa2 will fly by asteroid (98943) 2001 CC21 "Torifune » in July 2026 and rendezvous with rapidly-rotating asteroid 1998 KY26 in July 2031. The team demonstrated that the Mars impact probability is found to be 5.45 x 10^{-7}, and the impact probabilities for the Earth and the Moon are 0.0116 and 1.62 x 10^{-9}, respectively.
- The Panel acknowledges that the proposed Categories satisfies the COSPAR PP requirements

PPP Session and Panel at the COSPAR Symposium: *"Space Exploration 2025: A Summit on Humanity's Challenges and Celestial Solutions"* : 3-7 Nov. 2025, Cyprus

PP Panel led by N. Hedman



The PPP at the PP Meeting in April 2025, at DL

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Spreading the word…

Planetary
protection is cool !

PPP publications/communications

- More than 25 Publications in peer-reviewed journals since 2019 by the whole Panel or members of the PPP, related to Planetary protection
- More than 60 presentations/communications in national or international meetings as PPP
- New PTA special issue with papers by panel members and others.

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Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

The quest for habitats in the outer Solar System and how to protect exotic pristine environments

Athena Coustenis[a,*], Peter T. Doran[b], Karen Olsson-Francis[c], Olga Prieto-Ballesteros[d], François Raulin[e], Petra Rettberg[f], Olivier Grasset[g], Alexander Hayes[h], Christian Mustin[i], Niklas Hedman[j], Omar Al Shehhi[k], Eleonora Ammannito[l], Masaki Fujimoto[m], Timothy Haltigin[n], Vyacheslav Ilyin[o], Jing Peng[p], Praveen Kumar K[q], Mark A. Sephton[r], Silvio Sinibaldi[s], Yohey Suzuki[t], Jeremy Teo[u], Lyle G. Whyte[v], Kanyan Xu[w], Maxim Zaitsev[x]

PPP publications/communications

Planetary Protection for sustainable space exploration. *Phil. Trans. A special issue, 2025: in press.*

Olsson-Francis, Coustenis, Doran, Rettberg, Hedman, Worms, Eds

Manuscript Title	Author First Name	Author Last Name
Habitability and exchange processes on the Jovian moons: Implications for planetary protection measures	Gabriel	Tobie
Testing the hypothesis, 'planetary protection is expensive' from the ESA perspective	Silvio	Sinibaldi
Proposed updates to the COSPAR planetary protection policy for missions to Icy Worlds.	Peter	Doran
Planetary Protection for Safe and Sustainable Space Exploration	Karen	Olsson-Francis
An Ensemble Binning Approach to Identify Functional Diversity in Cleanroom Environments	Michael	Macey
Isolator/Glovebox Technical Challenges for the Curation of Samples Returned from Mars	John M. Christopher	Holt
The COSPAR Panel on Planetary Protection and the COSPAR Policy on Planetary Protection: An Overview of Governance and Activities	Niklas	Hedman
Co-enrichment of Ce and organics in microbe-like structures at the deep-sea ferromanganese crust surface	Yohey	Suzuki
Planetary Protection Considerations for Dragonfly at Titan	Ralph	Lorenz
Survival limits of psychrotolerant microorganisms with relevance for planetary protection of the icy moons	Tommaso	Zaccaria

COSPAR PPP activities 2025 : communications/Workshops

(KISS) Return from all across the Solar System
25 February 2025
Presentation of PP by A. Coustenis & P Doran

Europa Clipper Webinars
Conference, 8 April 2025
Presentation of PP by P. Doran & A. Coustenis

EGU 2025 :
28 April-2 May, Vienna
PP at a great debate by A. Coustenis

NASEM Space Science Week SSB/CoPP Meeting,
3 April 2025, DC
Presentation of PPP activitiies by P. Doran, A. Coustenis

Space Resources Week,
19-21 May 2025, Luxembourg
Presentation of PPP activitiies by N. Hedman

Flight Workshop
3-5 June 2025, Xi'an, China
Presentation of PP Policy by A. Coustenis

12th IAA/AIDAA Symposium on Future Space Exploration.
9-11 June 2025, Torino, Italy
Presentation by A. Coustenis & PPP

COSPAR PPP activities 2025 : communications/Workshops

AOGS 2025
28 July-1 Aug. 2025, Singapore
A. Coustenis and the PPP

IAC 2025
Sydney, AU
29 Sept.- 3 Oct. 2025
Presentation of PP by A. Coustenis & the PPP

UN General Assembly - Science Summit 2025: Decolonising Science
24 Sept. 2025, remotely
PP in the Panel with N. Hedman

NASEM/CAPS 2025
Irvine,
8 Oct. 2025
Presentation of PP by Peter Doran

COSPAR Symposium
3-7 Nov. 2025, Cyprus
Session PPP and Presentations by N. Hedman and several PPP members and guests

AGU 2025
New Orleans, USA
15-19 Dec. 2025
Presentation of PP by P. Doran & the PPP

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The COSPAR PP Policy
(a living document…)

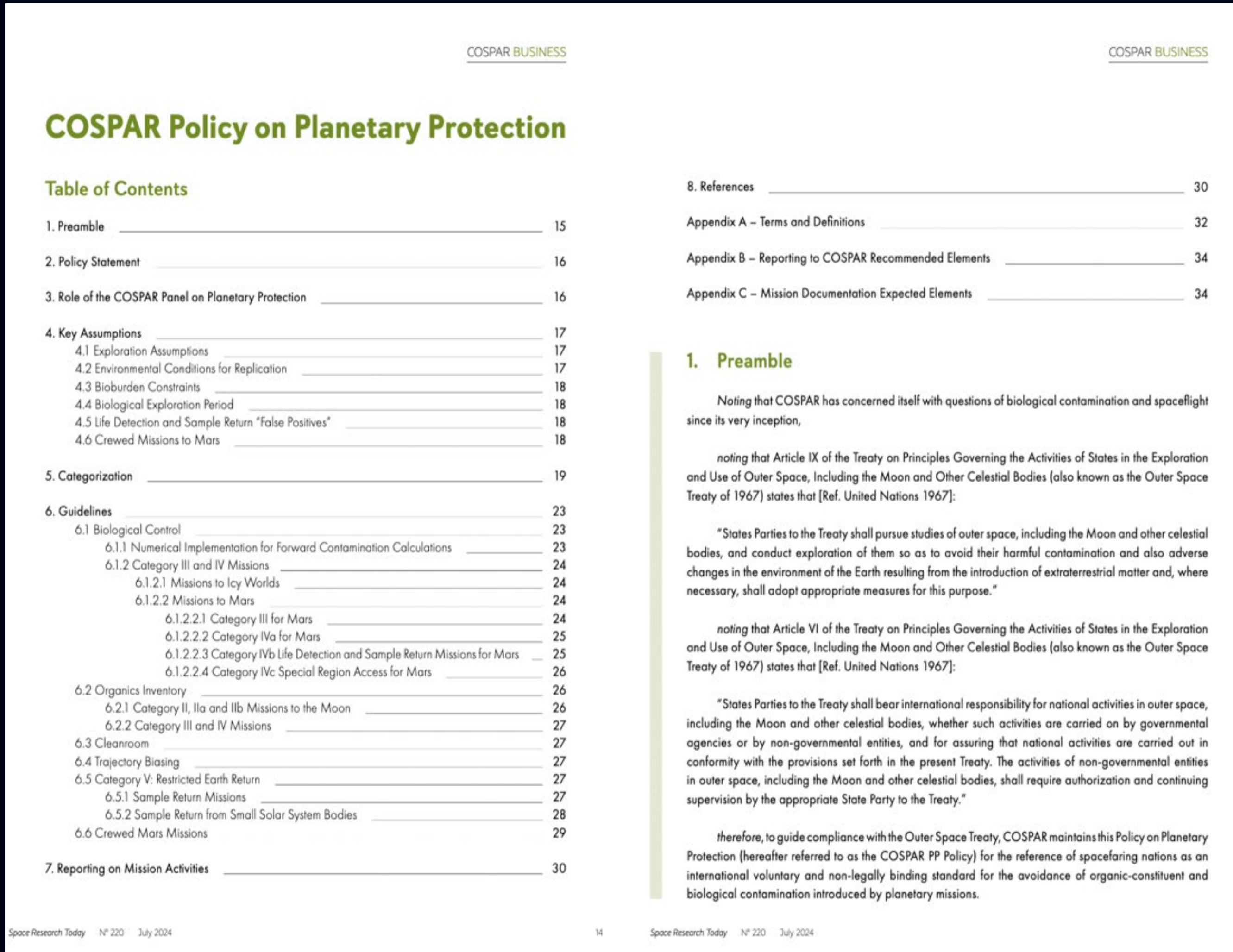
The COSPAR PP Policy: a living document

The international standards for planetary protection have been developed through consultation and discussion between the COSPAR PPP, the scientific community and the national space agencies. The resulting COSPAR Policy:

- has a non-legally binding status
- Is updated on a fairly regular cadence based on new findings in the peer-reviewed astrobiology literature (including from our panel) and expert workshops
- Has relied constructively on the findings of NAS reports
- Published in Space Research Today and available on our website

The Policy

Current Policy : In SRT 220, 12 July 2024
New Policy coming up in Jan. 2026



COSPAR Policy on Planetary Protection

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1. Preamble

Noting that COSPAR has concerned itself with questions of biological contamination and spaceflight since its very inception,

noting that Article IX of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (also known as the Outer Space Treaty of 1967) states that [Ref. United Nations 1967]:

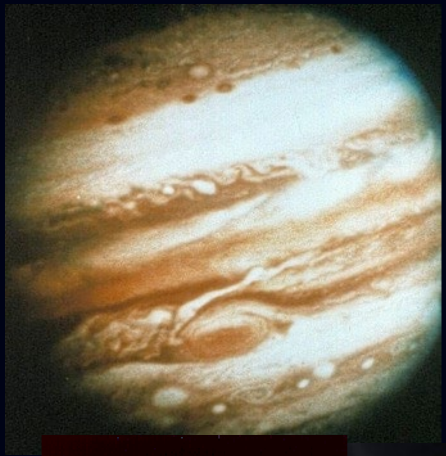
"States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose."

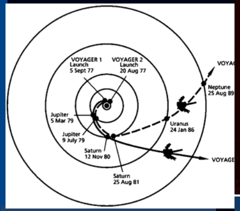
noting that Article VI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (also known as the Outer Space Treaty of 1967) states that [Ref. United Nations 1967]:

"States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty."

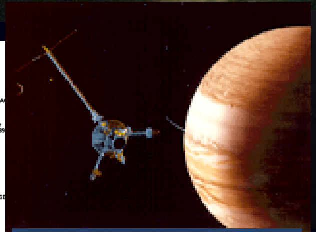
therefore, to guide compliance with the Outer Space Treaty, COSPAR maintains this Policy on Planetary Protection (hereafter referred to as the COSPAR PP Policy) for the reference of spacefaring nations as an international voluntary and non-legally binding standard for the avoidance of organic-constituent and biological contamination introduced by planetary missions.

Giant planets and icy moons



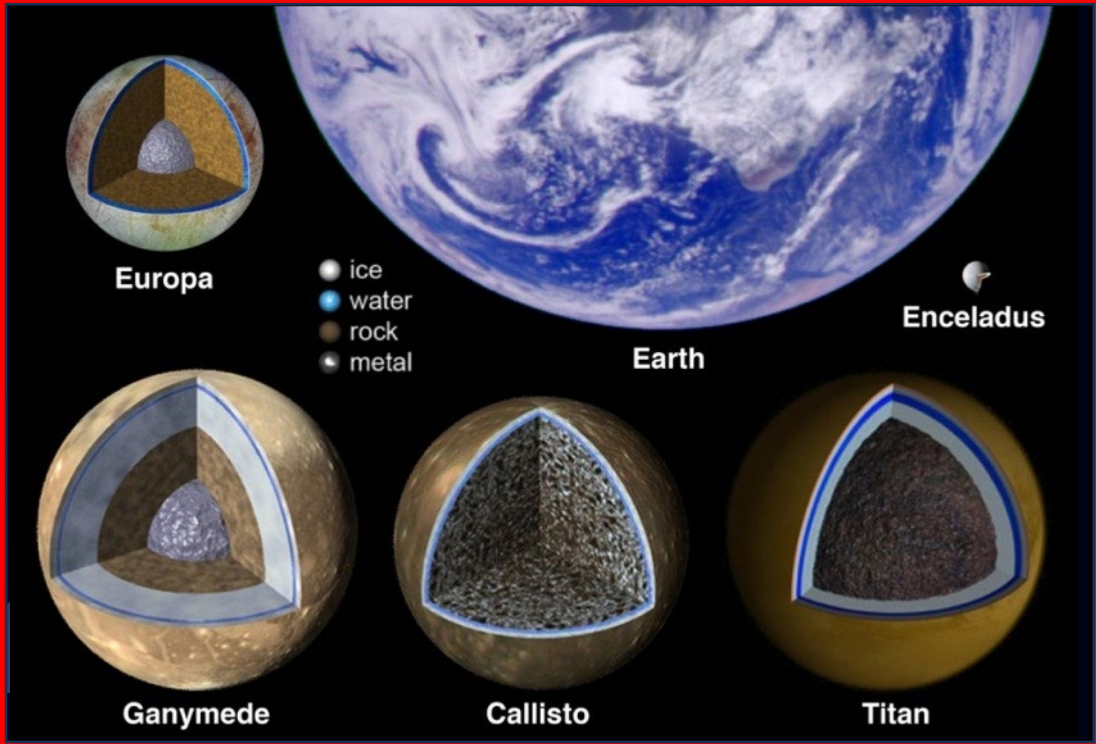


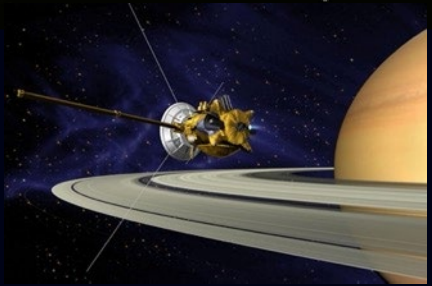
Voyager
1980s



Galileo
1995-2000

JUNO
2016-

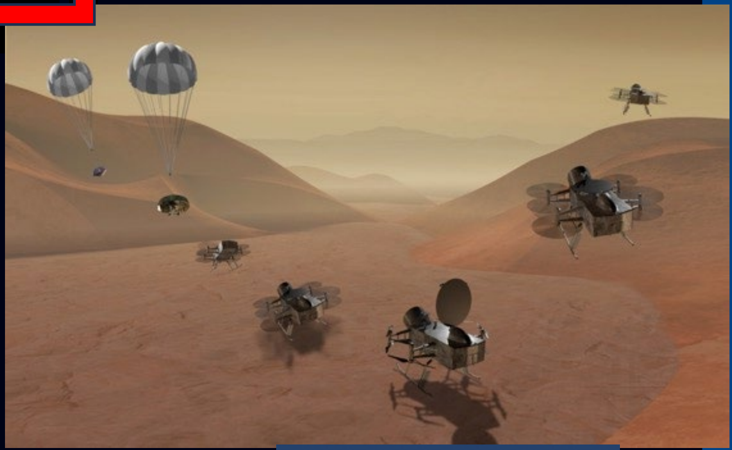




Cassini-Huygens
2004-2017

JUICE
Launched: April 2023

Europa Clipper
Launched Oct. 2024



Dragonfly
Launch: 2028

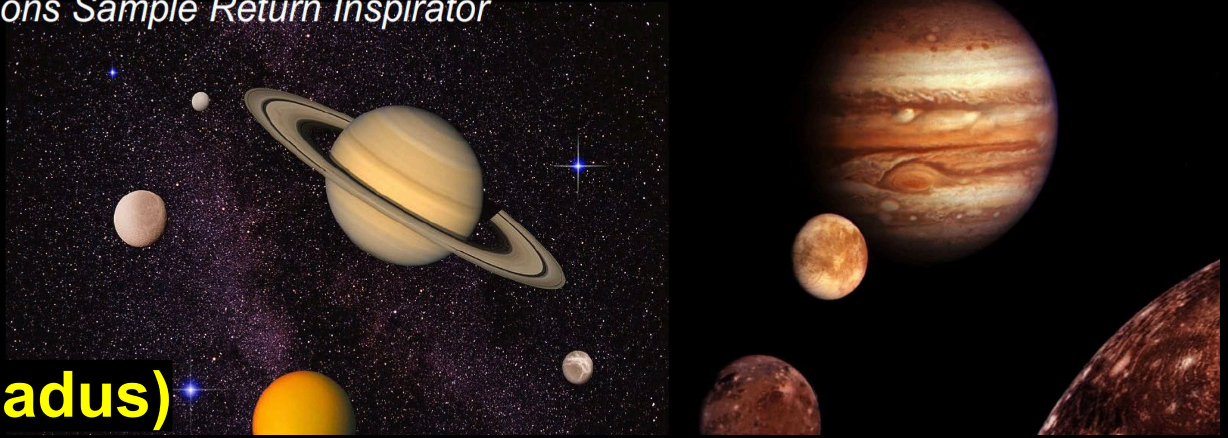
A mission to the moons of Jupiter or Saturn

esa

The ambitious next destination for the Science Programme

A competitively selected team of European scientists has started to define the first "Large" mission of Voyage 2050…

… also look into much more ambitious mission profiles, paving the way for the *Icy Moons Sample Return Inspirator*



ESA L4: Moons of the Giant Planets (Enceladus)

Exploring the issues of habitability of ocean worlds, searching for biosignatures, and studying the connection of moon interiors, near-surface environments, and the implications for the exchange of mass and energy into the overall moon-planet system. This theme follows the science from Cassini-Huygens and expected scientific return from JUICE.

NAS Decadal: 2nd Flagship, after Uranus, to be an orbilander to Enceladus

L4 (Enceladus) launch foreseen around 2041, while the PSDS advocated for Enceladus Orbilander launch ~2038 and Enceladus science operations ~2050-2054. This is in similar timeframes.

Planetary Protection of Icy Worlds

- PPOSS, Planetary Protection of the Outer Solar System
- 2016-2018 Project led by the European Science Foundation. COSPAR was involved throughout the multi-year-long process
- Made a number of recommandations including that the Policy should include a generic definition of the environmental conditions potentially allowing Earth organisms to replicate

COSPAR POLICY ON PLANETARY PROTECTION
Prepared by the COSPAR Panel on Planetary Protection (subcommittee led by Peter Doran) and approved by the COSPAR Bureau on 3 June 2021.

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

Planetary Protection of Icy Worlds

- COSPAR PPP Subcommittee formed in 2022. Peter Doran (Chair), Alex Hayes, Olivier Grasset, Olga Prieto-Ballesteros, Athena Coustenis, Kanyan Xu, Timothy Haltigin. Charge was to look at changes needed for Icy Worlds in the Policy
- Resulted in a number of recommendations discussed at a number of meetings and eventually in this paper
- The New Icy Worlds Policy does not affect current missions

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The COSPAR planetary protection policy for missions to Icy Worlds: A review of history, current scientific knowledge, and future directions

P.T. Doran[a,*], A. Hayes[b], O. Grasset[c], A. Coustenis[d], O. Prieto-Ballesteros[e], N. Hedman[f,1], O. Al Shehhi[g], E. Ammannito[h], M. Fujimoto[i], F. Groen[j], J.E. Moores[k], C. Mustin[l], K. Olsson-Francis[m], J. Peng[n], K. Praveenkumar[o], P. Rettberg[p], S. Sinibaldi[q], V. Ilyin[r], F. Raulin[s], Y. Suzuki[t], K. Xu[u], L.G. Whyte[v], M. Zaitsev[w], J. Buffo[x], G. Kminek[q], B. Schmidt[b]

During this process we sought community input with presentations to/at: 1) NAS CoPP multiple times, 2) OPAG, 3) SBAG, 4) COSPAR Symposium in Busan, 5) Inaugural Planetary Protection week in London, UK, and 6) the European Science Foundation

Community input gathered was used to produce a second peer-reviewed paper now in press in Phil. Trans. R. Soc. A

OUTCOMES

Definition for Icy Worlds (from Doran et al. In press)

"Icy Worlds" over e.g. "Ocean Worlds" for PP policy. You don't need an ocean for habitability. A body could have a slushy layer or just layer of warm ice and be potentially habitable to Earth life (forward contamination).

- *Currently only "Icy Moon(s)" appears in the policy. Not all bodies of concern are moons*

New Definition for Icy Worlds

"Icy Worlds in our Solar System are defined as all bodies with an outermost layer[1] that is believed to be predominantly water ice by volume and have enough mass to assume a nearly round shape[2]"

1. Outermost layer here refers to the shell of the body, or what would canonically be considered the crust of a terrestrial planet. We are explicitly excluding thin extrinsically derived veneers, such as the organic regolith on Titan or meter-scale dark dust that covers Iapetus
2. Here nearly round refers to a shape that is consistent with hydrostatic equilibrium, i.e., a body that has sufficient mass such that self-gravity has overcome rigid body forces

This definition includes dwarf planets like Pluto, but rejects small bodies including comets, trojans, irregular moons, TNOs (centaurs / KBOs),...

Evolution of Special Regions limits of life

NRC PREVCOM 2006 – All of Mars is Special

Study	Low T record (°C)	Low T limit with buff (°C)	Low Aw record	Low Aw limit with buff
MEPAG SR-SAG (Beaty et al. 2006)	-15	-20	0.62	0.5
COSPAR Colloquium (Kminek et al. 2010)	-15	-25	0.61	0.5
MEPAG SR-SAG2 (Rummel et al. 2014)	-18	-23	0.605	0.5
Rev. of SR-SAG2 Report (NASEM, ESF, ESA 2015)	-18	-25	0.605	0.5
COSPAR Panel on PP Colloquium (Hipken & Kminek 2016)	-18	-28	0.605	0.5

Since 2015, the Aw record has become 0.585 (Stevensen et al. 2017. New theoretical Aw lower limit for anabolic activity of 0.540 (Paris et al., 2023)

Proposal

We propose to define new indices for use throughout the solar system based on the currently established limits of Earth Life with regards to temperature and water activity.

LLT = Lower Limit for Temperature (lower limit for replication).

Current LLT -28°C

LLAw = Lower Limit for Water Activity. Current LLAw is 0.5

10. Category III/IV/V requirements for Europa and Enceladus [15]

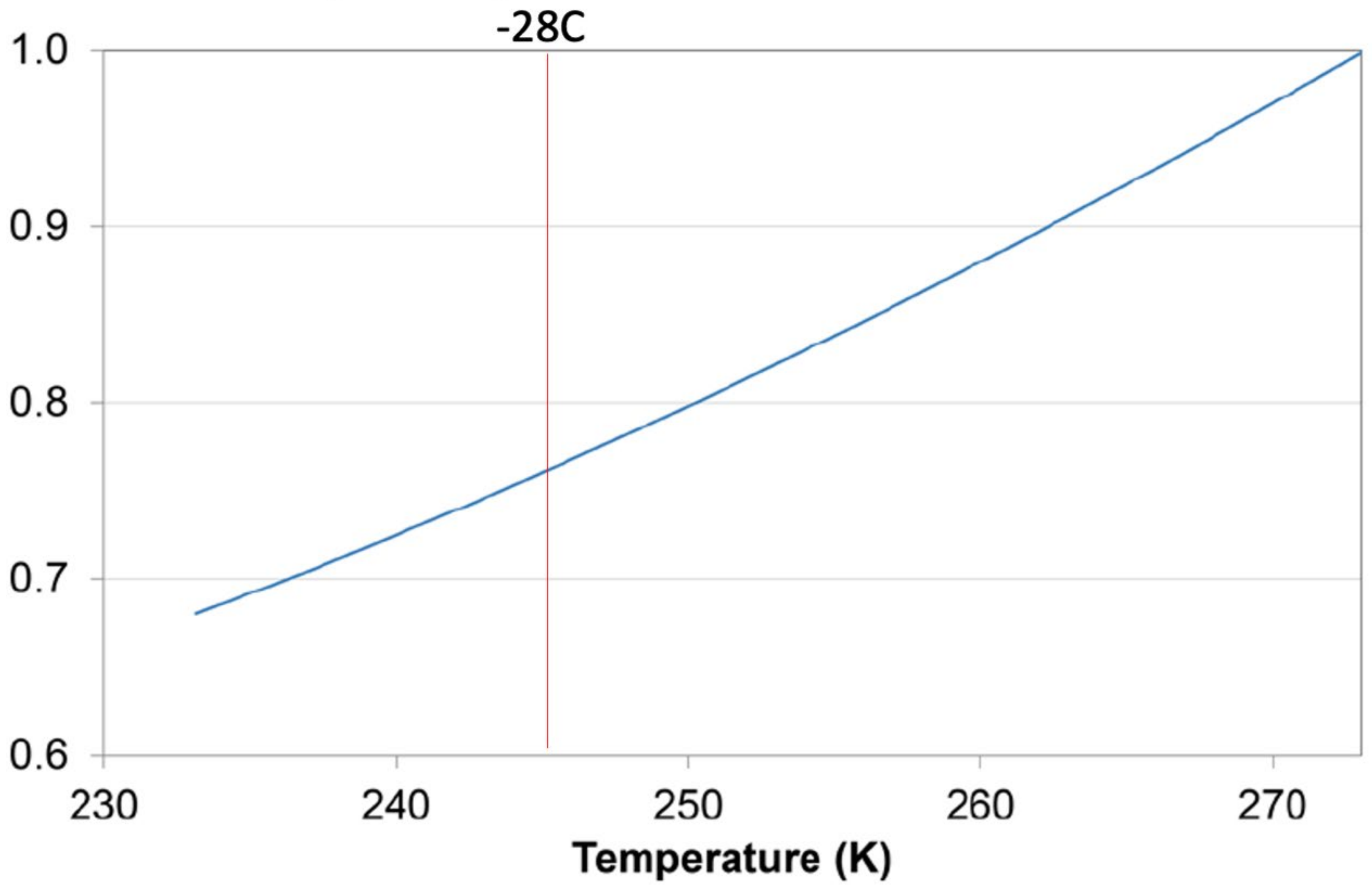
10.1. Missions to Europa and Enceladus (Ref: [15], [20], [21], [22], [23], [24])

Category III and IV. The biological exploration period for Europa and Enceladus is defined to be 1000 years; this period should start at the beginning of the 21st century. Requirements for Europa and Enceladus flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of Europan or Enceladan subsurface liquid water to less than $1x10^{-4}$ per mission. The probability of inadvertent contamination of a Europan or Enceladan ocean of $1x10^{-4}$ applies to all mission phases including the duration that spacecraft introduced terrestrial organisms
remain viable and could reach a sub-surface liquid water environment. The calculation of this probability should include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

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

- Current policy only refers to Europa and Enceladus
- Current policy identifies encountering liquid water as a trigger for concern, but cold brines below -28^oC should be uninhabitable to Earth life.
- Where we should start to be concerned is not when we reach detectable liquid water, but when the ice cap gets above -28^oC
- There is a well documented cryoecosystem on Earth in relatively warm ice.

In ice, A_w is well above the limit when temperature is at -28C, so we can focus on just temperature as limiting



Sippola and Taskinen 2018, Activity of Supercooled Water on the Ice Curve and Other Thermodynamic Properties of Liquid Water up to the Boiling Point at Standard Pressure. Journal of Chemical & Engineering

It all simplifies to temperature and connectivity

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

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

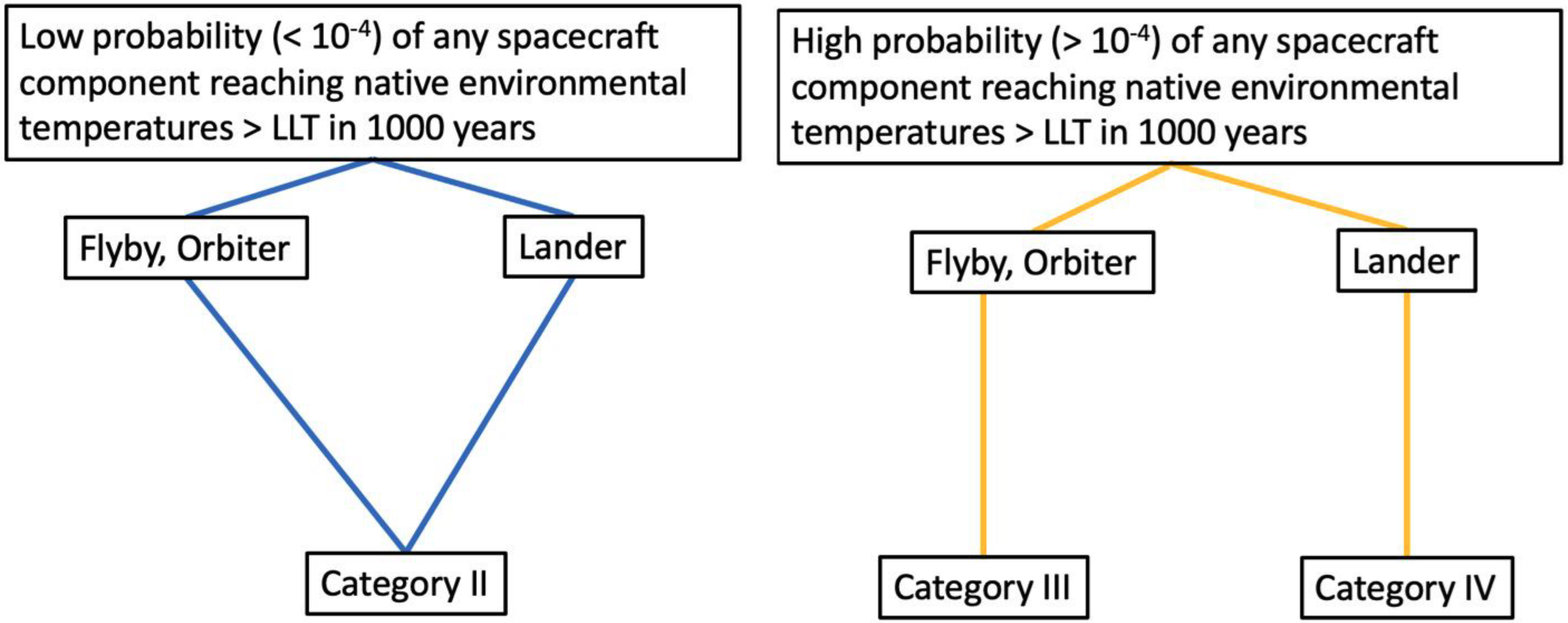
- Ganymede (Jupiter) internal ocean ~3 X larger than Europa, but lacks clear evidence of a connection
  T_{surf}=-113^{o}C (midday at equator, colder toward poles / other times)

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

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

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

2 step process: Step 1 shown here is does mission stay at Cat III/IV (default) or drop to Cat II?



LLT = Lower Limit for Temperature (currently -28˚C)
PBE= Period of Biological Exploration (currently 1000 years)

Step 2 only required if mission is Cat III/IV and is the probability calculation of an inoculation event in a region <LLT

Sample return questions derived from NRC (1998) and currently in policy for "Sample Return from Small Solar System Bodies"

For containment procedures to be necessary, an answer of "no" or "uncertain" needs to be returned for all six questions

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 CO_2 or carbonates *and* an appropriate source of reducing equivalents)[1] 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?

NRC. 1998. Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making. Washington, DC: The National Academies Press. https://doi.org/10.17226/6281.

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Next steps for Icy Worlds new requirements implementation in Policy

- Establish a new definition of Icy Worlds for use in Planetary Protection: “Icy Worlds in our Solar System are defined as all bodies with an outermost layer that is believed to be predominantly water ice by volume and have enough mass to assume a nearly round shape”
- 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 -28^{o}C, respectively).
- Establish LLT as a parameter to assign categorization for Icy Worlds missions (subject to 1000-year period of biological exploration).
- Establish any sample return from an Icy World as Category V restricted Earth return unless all six questions listed for small bodies can be answered as “no” or uncertain
- *Develop policy incorporating these changes and new publication (Doran et al., PTA, in press)*
- *Approval by COSPAR Bureau in November 2025 and implementation in updated Policy to be*

ANNOTATED SCREEN CAPS OF NEW POLICY APPROVED BY COSPAR BUREAU

4.2 Environmental Conditions for Replication

Given current understanding, the limiting physical environmental parameters in terms of water activity and temperature thresholds that should be satisfied at the same time to allow the replication of terrestrial microorganisms are [Rummel et al. 2014, Kminek et al. 2016 and Doran et al. 2024]:

- Lower limit of water activity (LLAw) : 0.5
- Lower limit of temperature (LLT): -28˚C

Introduce new acronyms for LoL

Both of these limits include margins below the reported limits of terrestrial biology [Rummel et al. 2014, Kminek et al. 2016].

6.1.2 Category III and IV Missions

DEFINITION FOR ICY WORLDS

6.1.2.1 Missions to Icy Worlds

Icy Worlds in our Solar System are defined as all bodies with an outermost layer[1] that is predominantly water ice by volume and that have enough mass to assume a nearly round shape[2] [Doran et al. 2026]. A list of currently known Icy Worlds appears in Appendix D.

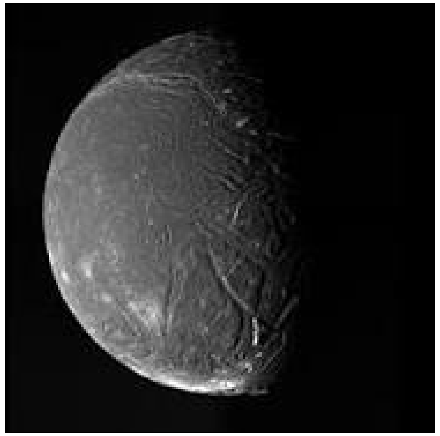
By default, missions to Icy Worlds are considered either Category III (Flyby/Orbiter) or Category IV (Lander/Probe). Icy Worlds may be classified as a Category II mission but must be substatinated by an analysis that demonstrates that the probability of introducing any component of the spacecraft into >LLT environments within the PBE of 1000 years is $<1 \times 10^{-4}$ (Figure 2). This analysis should address both the existence of such environments as well as the prospects of accessing them. This probability calculation should include, at a minimum:

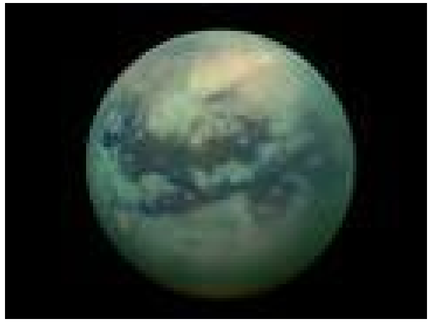
STEP 1

- The probability of the spacecraft reaching the surface of either the target body or any other body of interest in the target system (e.g., another satellite in a Giant Planet system);
- Worst-case assumptions for impact conditions (angle, velocity, etc.) with the target body, and;
- The mechanisms and timescales of transport to an environment where temperatures exceed LLT.

[1] "Outermost layer" here refers to the shell of the body, or what would canonically be considered the crust of a terrestrial planet. We are explicitly excluding thin extrinsically derived veneers, such as the organic regolith on Titan or meter-scale dark dust that covers Iapetus.

[2] Here "nearly round" refers to a shape that is consistent with hydrostatic equilibrium, i.e., a body that has sufficient mass such that self-gravity has overcome rigid body forces.





Body	Category	Current Classification
2002 MS_4	Dwarf Planet[2], Cubewano[3] (TNO)[4]	II
Ariel	Moon of Uranus	II
Callisto	Moon of Jupiter	II
Ceres	Dwarf Planet	II
Charon	Moon of Pluto	II*
Dione	Moon of Saturn	II
Enceladus	Moon of Saturn	III/IV
Eris	Dwarf Planet, Scattered Disk Object (TNO)	II
Europa	Moon of Jupiter	III/IV
Ganymede	Moon of Jupiter	II*
Gonggong	Dwarf Planet, Scattered Disk Object (TNO)	II
Haumea	Dwarf Planet, Haumeid (TNO)	II
Iapetus	Moon of Saturn	II
Makemake	Dwarf Planet, Cubewano (TNO)	II
Mimas	Moon of Saturn	II
Miranda	Moon of Uranus	II
Oberon	Moon of Uranus	II
Orcus	Dwarf Planet, Plutino (TNO)	II
Pluto	Dwarf Planet, Plutino (TNO)	II*
Quaoar	Dwarf Planet, Cubewano (TNO)	II
Rhea	Moon of Saturn	II
Salacia	Dwarf Planet, Cubewano (TNO)	II
Sedna	Dwarf Planet, Sednoid (TNO)	II
Tethys	Moon of Saturn	II
Titan	Moon of Saturn	II*
Titania	Moon of Uranus	II
Triton	Moon of Neptune	II*

[3]Classical Kuiper Belt Object
[4]Trans-Neptunian Object

RATIONALE FOR CERES BEING AN ICY WORLD

For the purposes of this policy, Ceres is included as an Icy World. While current knowledge suggests that there are regions of Ceres' surface and near-subsurface that may not be predominantly composed of water ice [Kurokawa et al. 2020, McCord et al. 2022] and water activity may be below LLAw, the general community consensus is that Ceres is an icy body with an outermost layer that is greater than 50% water ice by volume [Park et al. 2020] and which shows evidence for the presence of regional, possibly extensive liquid at depth, and local expressions of recent and potentially ongoing activity [Castillo-Rogez et al. 2025]. From a policy perspective, categorizing Ceres as an Icy World represents a conservative approach.

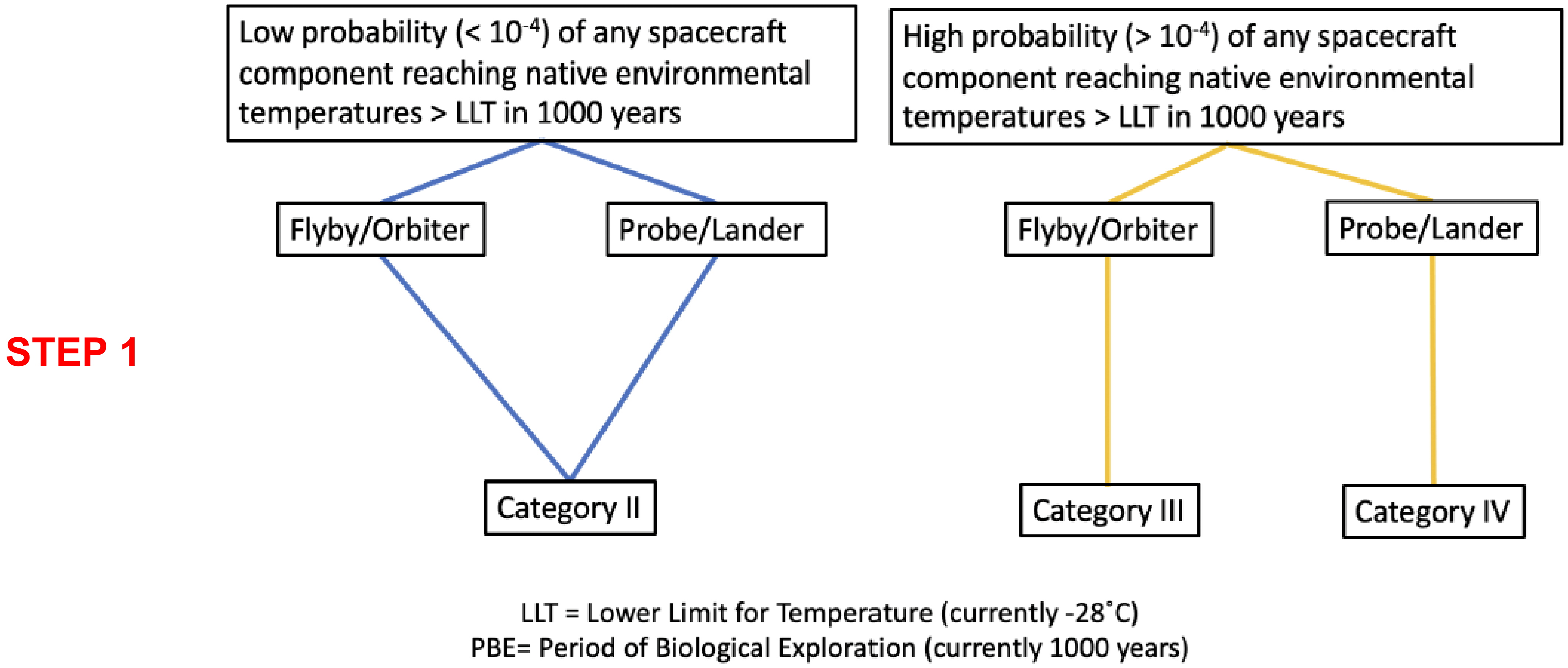


Figure 2: Flow diagram of first step in determining categorization of an Icy World [from Doran et al. 2026]

GUIDENCE ON COMPLETING STEP 1

For guidance on best-practices for determining the above parameters, see the NASA (https://ntrs.nasa.gov/api/citations/20240016475/downloads/PlanetaryProtection_Hdbk_2024_Final_For508ing_comp.pdf) or International (https://cosparhq.cnes.fr/assets/uploads/2021/02/PPOSS_International-Planetary-Protection-Handbook_2019_Space-Research-Today.pdf) handbooks. Examples of calculations that have supported the assignment of Category II to Icy World missions include Grasset et al. [2013] for the JUICE mission to Ganymede, and Lorenz et al. [2026] for the Dragonfly mission to Titan. Grasset et al. [2013], in particular, demonstrated that transport to in situ environments in Ganymede's ice shell with temperatures > LLT would take at least 7,000 years for a range of impact conditions.

The potential presence of shallow subsurface water pockets and plumes on Europa [Schmidt et al. 2011, Sparks et al. 2016] and Enceladus [Hansen et al. 2006, Postberg et al. 2011] suggest that it would be very difficult to successfully demonstrate that the probability of introducing any component of the spacecraft into >LLT environments within the PBE of 1000 years is < 10^{-4}. For missions to these bodies, the default assignment of Category III (flyby/orbiter) or Category IV (probe/lander) will likely be maintained and planetary protection measures such as bioburden reduction would then will be necessary. Such missions will require the use of cleanroom technology, as well as the monitoring of spacecraft assembly facilities to understand the bioburden and its microbial diversity, including specific relevant organisms. Relevant organisms are Earth organisms potentially present on the spacecraft that could survive the spaceflight environment, the environment at the icy moon and can replicate in Icy Worlds subsurface >LLT environments. Specific methods should be developed and validated to identify, enumerate and eradicate problematic relevant organisms as necessary to achieve the 1 x 10^{-4} requirement.

STEP 2 IF NEEDED (NOT NEEDED IF STEP 1 RESULTS IN CAT II)

6.1.2.1.1 Category III for Icy Worlds

Category III missions to Icy Worlds must demonstrate that the probability of introducing a viable terrestrial organism into environments with T>LLT (i.e., creating a potential biological inoculation event) within the PBE of 1000 years is $<1 \times 10^{-4}$. This analysis should expand upon the calculations in Section 6.1.2.1 used for categorization that assessed the probability of the spacecraft accessing >LLT environments and include a conservative estimate of poorly known parameters and address factors such as:

- Bioburden at launch;
- Cruise survival for contaminating organisms;
- Organism survival in the space environment adjacent to the target body;
- The probability of contaminating organisms surviving landing/impact, and;
- Organism survival and proliferation before, during, and after subsurface transfer.

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6.1.2.1.2 Category IV for Icy Worlds

Category IV missions to Icy Worlds should demonstrate compliance with the following bioburden cleanliness constraints:

- All of the constraints listed for Category III missions to Icy Worlds in Section 6.1.2.1.1 above, and;
- In the case that an environment with temperature > LLT is accessed through horizontal or vertical mobility we note that the entire landed system must meet the 10^{-4} probability of contamination over the PBE. For any subsystems that directly contacts the environment with temperature > LLT, the probability calculation must consider potential recontimation during the mission prior to accessing the region.

Table 1. Planetary Protection Categories in relation to target bodies. Please note that target body lists and categorizations are updated as needed to reflect new discoveries and the most current scientific understanding.

Category	Mission Type	Target Body
I	Flyby[1]/Orbiter, Probe/Lander	Undifferentiated, metamorphosed asteroids; Io
II No more Cat II*	Flyby/Orbiter, Probe/Lander	Venus[2]; Moon (Cat. II, IIa & IIb); Comets; Carbonaceous Chondrite Asteroids; Jupiter; Saturn; Uranus; Neptune; Icy Worlds[3]; Kuiper-belt objects that are not classified as Icy Worlds
III	Flyby/Orbiter	Mars; Icy Worlds[3]
IV	Probe/Lander	Mars (Cat. IVa, IVb, &.IVc); Icy Worlds[3]
V "Unrestricted Earth return"	-	Venus; Moon; Small Solar System Bodies and Icy Worlds without an answer of "no" or "uncertain" to all 6 questions in section 6.5.2
V "Restricted Earth return"	-	Mars; Small Solar System Bodies and Icy Worlds with an answer of "no" or "uncertain" to all 6 questions in section 6.5.2

[1]Flybys include gravity assist maneuvers.

[2]For the categorization of Venus, see Zorzano-Meier et al. [2023].

[3]By default, missions to Icy Worlds are considered either Cat. III (Orbiter) or Cat. IV (Lander). Assignment of these missions to category II must be supported by an analysis that determines the probability of introducing any component of the spacecraft into >LLT environments that may exist beneath their surfaces within the PBE of 1000 years. See Section 6.1.2.1 for more details.

6.5.2 Sample Return from Small Solar System Bodies and Icy Worlds

Missions to small Solar System bodies and Icy Worlds should determine if a mission is classified "Restricted Earth return" or not. This mission assessment should be undertaken with respect to the best multidisciplinary scientific advice, using the framework presented in the 1998 report of the US National Research Council's Space Studies Board entitled, Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making [National Research Council 1998]. Specifically, such a determination should address the following six questions for each body intended to be sampled:

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?

For containment procedures to be necessary ("Restricted Earth return"), an answer of "no" or "uncertain" needs to be returned to all six questions.

Table 2. Planetary Protection Categories sorted by Target. Please note that target body lists and categorizations are updated as needed to reflect new discoveries and the most current scientific understanding.

	LOCATION	TARGET BODY	MISSION TYPE	CATEGORY
INNER SOLAR SYSTEM	MERCURY	Mercury	Flyby[1]/Orbiter, Probe/Lander	I
			Earth sample return	V Unrestricted
	VENUS	Venus[2]	Flyby/Orbiter, Probe/Lander	II
			Earth sample return	V Unrestricted
	EARTH	Moon	Flyby/Orbiter, Probe/Lander	II, IIa, IIb
			Earth sample return	V Unrestricted
			Crewed missions	II, IIa, IIb
	MARS	Mars	Flyby/Orbiter	III
			Probe/Lander	IVa, IVb, IVc
			Earth sample return	V Restricted
			Crewed missions	See Sections 4.6 and 6.6
	ASTEROID BELT	Undifferentiated, metamorphosed asteroids	Flyby/Orbiter, Probe/Lander	I
			Earth sample return	V Unrestricted
		Carbonaceous Chondrite Asteroids	Flyby/Orbiter, Probe/Lander	II
			Earth sample return	V Unrestricted / Restricted
		Icy Worlds – Ceres[3]	Flyby/Orbiter	II / III
			Probe/Lander	II / IV
			Earth sample return	V Unrestricted / Restricted
	OTHERS	To-be-defined (TBD)	All	TBD

	OTHERS	To-be-defined (TBD)	All	TBD
OUTER SOLAR SYSTEM	GIANT PLANETS	Jupiter, Saturn, Uranus, Neptune	Flyby/Orbiter, Probe/Lander	II
		Io	Flyby/Orbiter, Probe/Lander	I
		Icy Worlds[3] - Moons	Flyby/Orbiter	II / III
			Probe/Lander	II / IV
			Earth sample return	V Unrestricted / Restricted
		Irregular moons	Flyby/Orbiter, Probe/Lander	II
			Earth sample return	V Unrestricted / Restricted
	TRANS-NEPTUNIAN REGION[4]	Comets	Flyby/Orbiter, Probe/Lander	II
			Earth sample return	V Unrestricted / Restricted
		Icy Worlds[3] - Transneptunian objects	Flyby/Orbiter	II / III
			Probe/Lander	II / IV
		Icy Worlds[3] - Dwarf planets & their moons	Flyby/Orbiter	II / III
			Probe/Lander	II / IV
		Kuiper-belt objects that are not classified as Icy Worlds	Flyby/Orbiter, Probe/Lander	II
	OTHERS	To-be-defined (TBD)	All	TBD

[1]Flybys include gravity assist maneuvers.

[2]For the categorization of Venus, see Zorzano-Meier et al. [2023].

[3]By default, missions to Icy Worlds are considered either Cat. III (Orbiter) or Cat. IV (Lander). Assignment of these missions to category II must be supported by an analysis that determines the probability of introducing any component of the spacecraft into >LLT environments that may exist beneath their surfaces within the PBE of 1000 years. See Section 6.1.2.1 for more details.

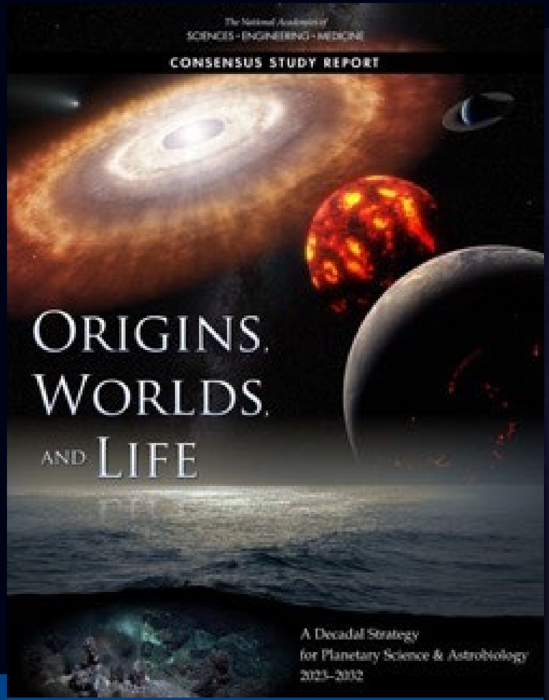
[4]Trans-Neptunian Region refers to the vast expanse of the Solar System beyond Neptune where, for example, the Kuiper Belt is located.

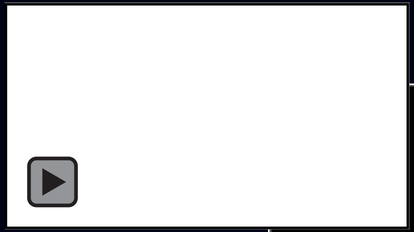
Current and future considerations

After the Moon, Venus, Mars Robotic exploration and small bodies…

- More small bodies, Mars and Moon… (future missions categorisation) ->*New review of knowledge gaps*
- Implementation of Icy Worlds findings in Policy
- Updates to the Policy for case-by-case assessment
- Space resources (ISRU) and other concerns

Some of these themes have been showcased in the NASEM OWL 2022 and ESA's Voyage 2050.





Mimas

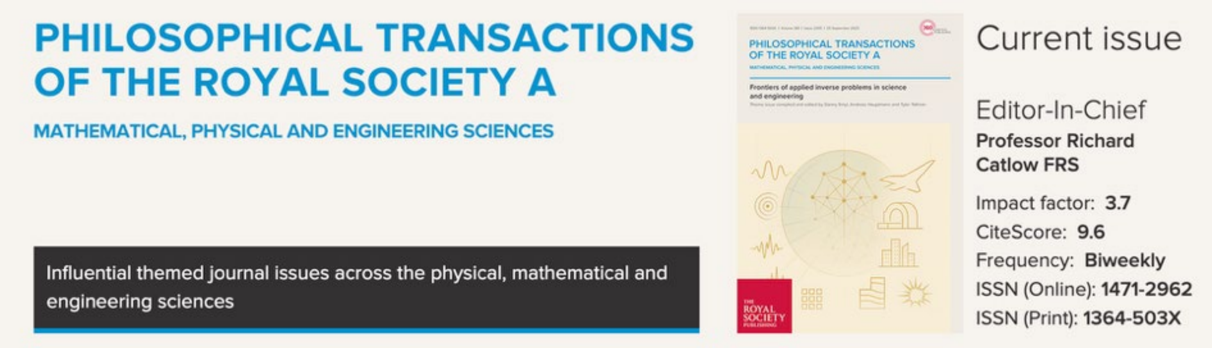
PPP current Task Groups

Subcommittee	Lead + Members
Moon subcommittee to work on lunar crewed mission/human missions Also recommend what we need add to the policy.	*Nick Benardini and Silvio Sinibaldi (Leads), P. Rettberg, A. Spry, E. Seasly, K. Olsson-Francis and M. Sefton*
Metagenomics subcommittee	*Nick Benardini (lead), Sinibaldi, Olsson-Francis, Lyle Whyte, Rettberg, Yohey Suzuki*
Icy Worlds subcommittee (completed)	*Peter Doran (lead), Prieto-Ballesteros, Hayes, Coustenis, Grasset, Xu Kanyan, Tim Halting*
Mars subcommittee to look at PP requirements for spores and special regions and also items not linked to spore assay	*Karen Olsson-Francis (Lead) Benardini, Seasly, Sinibaldi, Whyte, Rettberg and Doran*

PPP Recent publications (extract)

- The COSPAR Panel on Planetary Protection, 2020. « COSPAR Policy on Planetary Protection ». *SRT* 208.
- Coustenis, A., Hedman, N., Kminek, G., The COSPAR Panel on Planetary Protection, 2021. "To boldly go where no germs will follow: the role of the COSPAR Panel on Planetary Protection". *OpenAccessGovernment,* July 2021
- Fisk, L., Worms, J-C., Coustenis, A., Hedman, N., Kminek, G., the COSPAR PPP, 2021.Updated COSPAR Policy on Planetary Protection. *Space Res. Today* 211, August 2021. doi.org/10.1016/j.srt.2021.07.009
- Coustenis, A., The COSPAR Panel on Planetary Protection, 2021. « Fly me to the moon: Securing potential lunar water sites for research ». *OpenAccessGovernment,* Sept. 2021
- Olsson-Francis, K., Doran, P., et al., 2023. The COSPAR Planetary Protection Policy for missions to Mars: ways forward based on current science and knowledge gaps. *LSSR*, 36, p. 27-35.
- Zorzano MP, et al., 2023. The COSPAR Planetary Protection Requirements for Space Missions to Venus. *LSSR* 37, 18
- Coustenis, A., et al., 2023. Planetary protection: Updates and challenges for a sustainable space exploration. *Acta Astron.*, 210, 446-452. https://doi.org/10.1016/j.actaastro.2023.02.035
- Coustenis, A., et al., 2023. Planetary Protection: an international concern and responsibility. Frontiers in Astronomy and Space Sciences, *Front. Astron. Space Sci. 10:1172546.*

- **Spry, A., et al., 2024. Planetary Protection Knowledge Gap Closure Enabling Crewed Missions to Mars. Astrobiology, 24(3):230-274. doi: 10.1089/ast.2023.0092).**
- **Ehrenfreund, P., et al., PP Policy, SRT 220, 10-13 and 14-36.**
- **Doran, P., et al. 2024. The COSPAR Planetary Protection Policy for missions to Icy Worlds: A review of current scientific knowledge and future directions. LSSR, 41 pp. 86–99.**
- **Coustenis, and the PPP, 2025.The quest for habitats in the outer Solar System and how to protect exotic pristine environments. Acta Astronautica 233, 330-343.**
- ***Olsson-Francis et al., Eds, 2025. Royal Society Phil. Transactions A special issue, in press.***
- ***Ehrenfreund, P., the COSPAR PPP, 2025. New PP Policy, SRT, in press.***



Special Issue on Planetary Protection from the 1st COSPAR Planetary Protection Week, 22-25 April 2024, the Royal Society, London UK

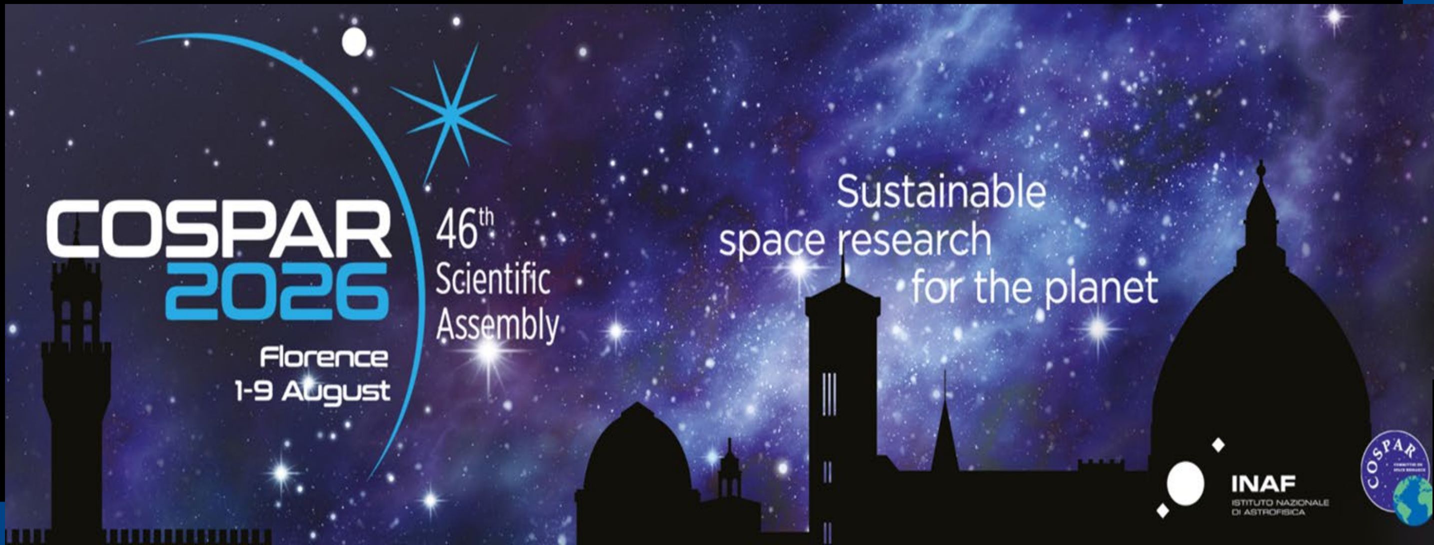
Authorship	Title
Tobie, G. et al.	Habitability and exchange processes on the Jovian moons: Implications for planetary protection measures
Sinibaldi et al.	Testing the hypothesis, 'planetary protection is expensive' from the ESA perspective
Doran et al.	Proposed updates to the COSPAR planetary protection policy for missions to Icy Worlds
Olsson-Francis et al.	Planetary protection for safe and sustainable space exploration
Macey et al.	An Ensemble Binning Approach to Identify Functional Diversity in Cleanroom Environments
Holt et al.	Isolator/Glovebox Technical Challenges for the Curation of Samples Returned from Mars
Hedman et al.	The COSPAR Panel on Planetary Protection: An overview of governance and activities
Suzuki et al.	Co-enrichment of Ce and organics in microbe-like structures at the deep-sea ferromanganese crust surface
Lorenz et al.	Planetary Protection Considerations for Dragonfly at Titan
Zaccaria et al.	Survival limits of psychrotolerant microorganisms with relevance for planetary protection of the icy moons

Future PPP meetings

COSPAR Week, 20-22 Jan. 2026, Athens Greece
Registration for in person or virtual attendance on the PPP web site:

https://cosparhq.cnes.fr/scientific-structure/panels/panel-on-planetary-protection-ppp/

COSPAR General Assembly, Florence, Italy 1-9 Aug. 2026 https://www.cospar2026.org/



Closing thoughts

- Astrobiology research has been <u>critical</u> for establishing data-driven PP policy for exploration of solar system bodies
- On Mars many knowledge gaps (KGs) remain before relaxing PP protocols, or sending humans in responsible way. Many of these KGs need addressing by the astrobiology community.
- Importance of human exploration zones
- PP is often viewed as a cost burden on missions. A new paper from ESA (Sinibaldi, S. and Haldemann, 2025) shows that PP cost is anywhere from 1% to 5% of mission costs (based on ESA Cat III and IV missions).

Sinibaldi, S. and Haldemann, 2025. Testing the hypothesis, 'planetary protection is expensive' from the ESA perspective. Philosophical Transactions of the Royal Society A. in press.

Planetary protection:
For sustainable space exploration and to safeguard our biosphere

The Policy will continue to be updated but not in a rushed process. We give thorough consideration to all arguments and scientific inputs and make an informed decision

In the meantime, there is need for community input on science findings and research reserves or recent reports: Studies/Surveys/Workshop/Focused conferences?

- COSPAR maintains a non-legally binding planetary protection policy and associated requirements to guide compliance with the UN Outer Space Treaty. The COSPAR Policy is the only international framework for planetary protection

- **We appreciate our collaboration with CoPP and look forward to more interactions in the future, as well as exchanges on all PP matters**