Briefing and updates to CoPP from the COSPAR Panel on Planetary Protection

A. Coustenis, P. Doran, N. Hedman and

The COSPAR Panel on Planetary Protection

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

At the SSB/CoPP Meeting
3 April 2025

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**	Olga Prieto-Ballesteros (geology, astrobiology)
France/CNES	Christian Mustin (astrobiology)	**France**	François Raulin (chemistry, planetology)
India/ISRO	Praveen Kumar K (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 conditions)	**Russia**	Maxim Zaitsev (astrochem, organic chemistry)
UAE	Omar Al Shehhi (engineering)	**UAE**	Jeremy Teo (mechanical and bio engineering)
UK/UKSA	Karen Olsson-Francis (astrob., microbiology)	**UK**	Mark Sephton (astrobiology, organic geochem.)
USA/NASA	Elaine Seasly (contam. control, engineering)		
		COSPAR CIR Ex-officio	John Reed
NASEM Ex-officio	Colleen Hartman SB, ASEB & BPA Director	**UNOOSA Ex-officio**	Michael Newman

Invited commercial

And more

Framework for planetary protection

The Outer Space Treaty of 1967

International Responsibility

Article VI:

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

Planetary Protection

Article IX:

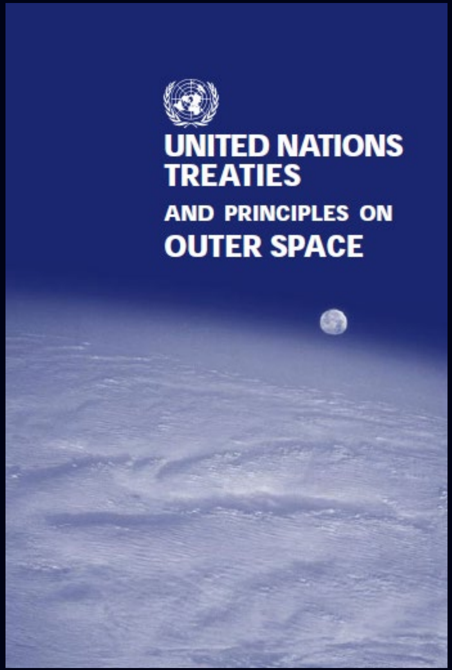
States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter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

Committee on Space Research (COSPAR)

- **Panel on Planetary Protection forms international consensus guidelines**
- **Defines PP Categories I – V based on target body and mission type**

Space agencies and experts

- Provide advice on current knowledge and future programs
- Implement Planetary Protection Policy to achieve compliance for Missions



- 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.*

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.

The PPP at the IICPPW in April in London and at the COSPAR General Assembly, July 2024 in Busan, South Korea

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; 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; **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*

Overview of COSPAR Panel on Planetary Protection Recent activities

COSPAR Panel on Planetary Protection Meetings/Sessions (2024-2025)

- **Inaugural International COSPAR PP Week (IICPPW):**
  22-24 April 2024, London, UK
- **Several Sessions at the COSPAR General Assembly:**
  13-21 July 2024, Busan, South Korea
- **Executive Meeting:** ***12 December 2024***
- **COSPAR PP Workshop :**
  14-16 April, Cologne, Germany

The Inaugural International COSPAR Planetary Protection Meeting:
22-24 April 2024 in London, The Royal Society

- **Monday 22 April**:
Welcome (UKSA); PPP Activities ; Probabilistic Risk Assessment ; Icy Worlds and astrobiology ; Limits of Life ; space missions to icy moons

- **Tuesday 23 April**: Mars Session: Habitability, agency reports on Mars Exploration ; Sample return facilities ; Robotic and human exploration of Mars ; Panel on PP in the commercial and private sector

- **Wednesday 24 April** : PPP Open session meeting : Activities and reports; briefing from space agencies; MSR ; Double Walled insulator ; Bayesian Statistics for PP ; Industry and commercial sector reports ; COSPAR 2024 Assembly and futur meetings

- **Thursday 25 April** *:* COSPAR PPP Closed session for members only and invited guests

The 2024 COSPAR General Assembly

13-21 July 2024, Busan, South Korea

https://www.cospar-assembly.org/assembly.php

PPP.1 Policy *(Conveners: A. Coustenis & N. Hedman)*
16 July 2024 (with **OPEN** and Closed sessions)

PPP.2 Planetary Protection Mission Implementation and Status *(Conveners: S. Sinibaldi & F. Groen)*
17 July 2024

PPP.3 Planetary Protection Research and Development *(Conveners: P. Doran & K. Olsson-Francis)*
14 July 2024

PPP Business Meeting : 17 July

Several talks from all interested parties and useful exchanges with the community at our PPP sessions !

COSPAR PP Workshop : *14-15 April, Cologne, Germany*

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)

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

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

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

PPP Recent publications (extract)

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

- The COSPAR Panel on Planetary Protection, 2020. « COSPAR Policy on Planetary Protection ». *SRT* 208.
- The COSPAR Panel on Planetary Protection, 2020. « Planetary Protection Policy: For sustainable space exploration and to safeguard our biosphere ». *Research Outreach* 118, 126-129.
- 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 M-P., et al., 2023. The COSPAR Planetary Protection Requirements for Space Missions to Venus. *LSSR*, 37, 18–24.
- 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, in press.**
- ***2025: Royal Society Phil. Transactions A special issue : (10 papers)***

COSPAR PPP activities 2024 – communications/Workshops

ESA PP course ‘Introduction to Planetary Protection’
21-24 Oct. 2024; Fraunhofer Inst., Stuttgart)

Organised by S. Sinbaldi,
presentations by N. Hedman & P. Rettberg

OPAG Meeting
19 June 2024

Presentation of PP Icy Worlds
Policy suggestions by A. Coustenis

UN-UNLUX SRW 2024
Working Group on Legal Aspects of
Space Resource Activities

Planetary Protection presentations
by P. Rettberg & N. Hedman

IAA
Busan, 13-20 July 2024

Presentation of PP
by A. Coustenis

IMEWG
6 Sept. 2024

Nick Benardini, Karen Olsson-
Francis, Silvio Sinibaldi

IAC
Milan, 13-18 Oct. 2024

Presentation of PP
by A. Coustenis

NASEM SSB/CoPP Meeting,
5 November 2024

Presentation of PPP activitiies by
P. Doran, A. Coustenis

COSPAR PPP activities 2024-2025 – communications/Workshops

ESA/ESF Planetary Protection Workshop on COSPAR Category II missions / Icy Worlds
10/11 December 2024

Organised by S. Sinbaldi,
Presentation by A. Coustenis

NASA Metagenomics Workshop
5-7 Nov. 2024, NASA AMES

Orgnisation : Elaine Seasly, Nick Benardini, Frank Groen et al.

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

AGU Congress
9-14 Dec. 2024

Presentation by A. Coustenis

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

IAC *Sydney,*
29 Sept.- 3 Oct. 2025

Presentation of PP by A. Coustenis & the PPP

12th IAA/AIDAA Symposium on Future Space Exploration.
9-11 June 2025, Torino, Italy

Presentation by Coustenis et al.

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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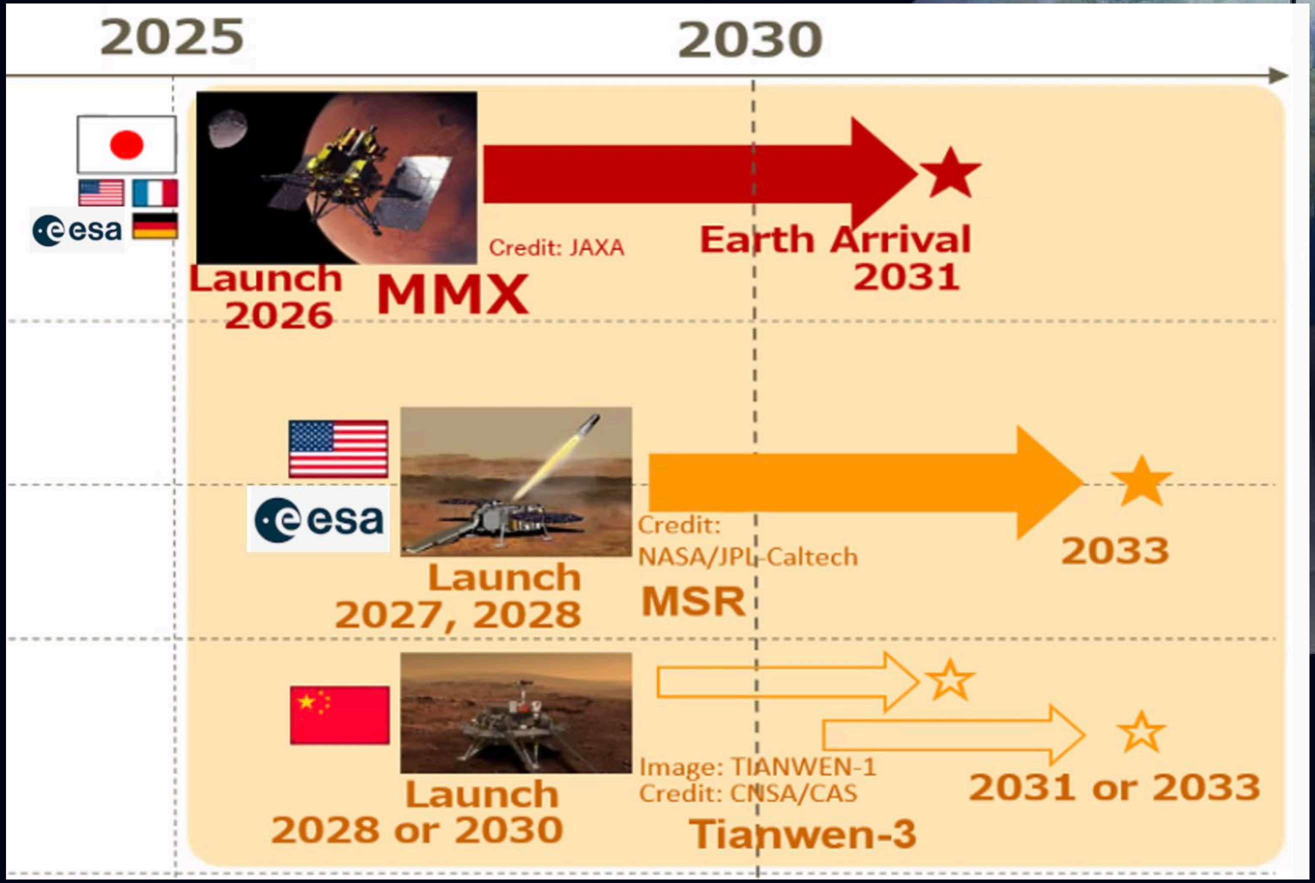
The COSPAR planetary protection requirements for space missions to Venus

Check for updates

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]

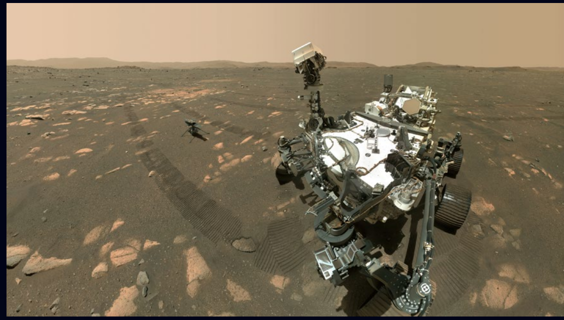
- ❑ ***No change in the Planetary Protection category for Venus*** : *the environmental conditions within the Venusian clouds are orders of magnitude drier and more acidic than the tolerated survival limits of any known terrestrial extremophile organism. Because of this, future orbital, landed or entry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

Mars and its moons (sample return era)

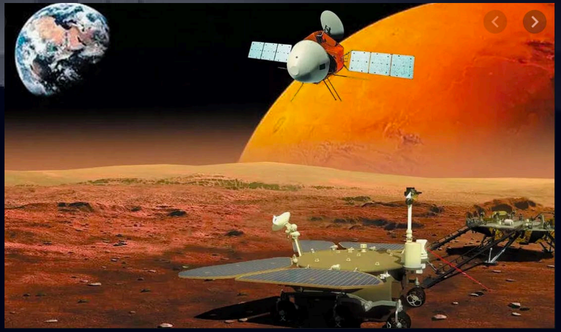


Al-Amal (Hope) – UAE
since 9 Feb. 2021

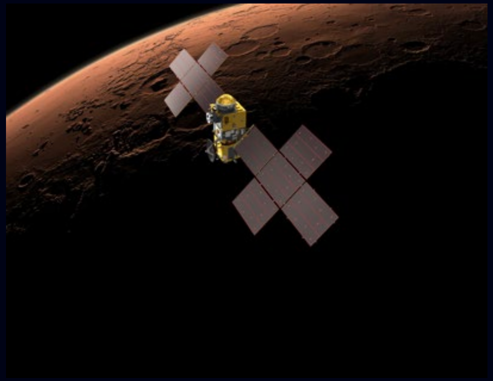
Mars 2020/Perseverance – NASA
since 18 Feb. 2021



Tianwen-1 – China
since 10 Feb. 2021

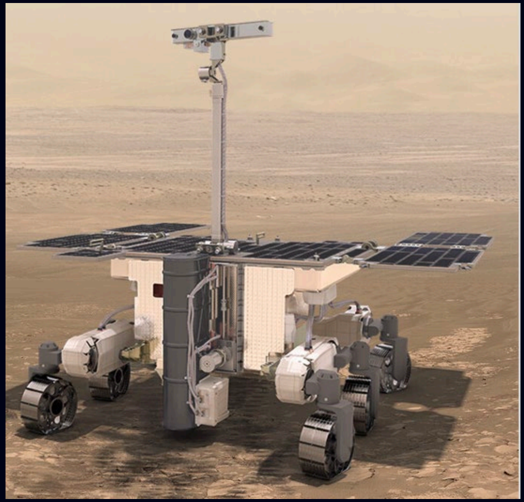


COSPAR PPP Mars-related recent activities



- ***Mars sample return and JAXA's Martian Moon Explorer (MMX)*: return of sample from Phobos (launch in 2026) : assigned planetary protection Cat. III for outbound and Cat V inbound : unrestricted Earth return.**

  See special issue *Life Sci. Space Res. 23 (2019)*



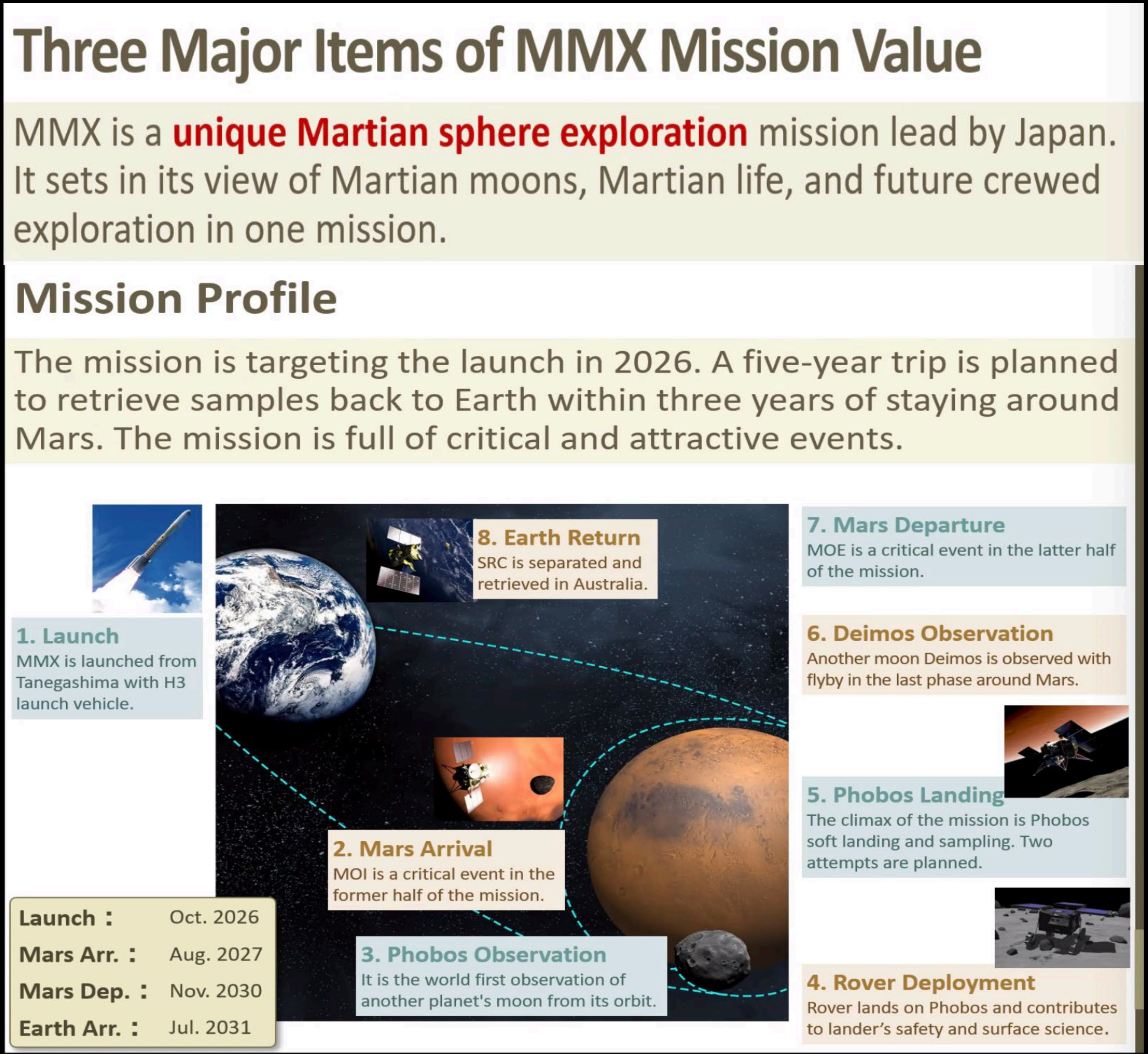
- ***Mars Robotic missions*** : Although the science underpinning the Policy is advancing, as highlighted in recent reports (e.g. NASEM 2021, Spry et al. 2021) and in the Panel's work, there are still several knowledge gaps that need to be addressed before they can be directly applied to accommodate the interest of the user. They 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* *Olsson-Francis et al., 2023. LSSR 36, 27-35*

- ***Mars Crewed missions*** : Series of Workshops with COSPAR support.

A publication highlights the scientific measurements and data needed for knowledge gaps closure.

Spry et al. (2024, Astrobiology, 24(3):230-274. doi: 10.1089/ast.2023.0092)

JAXA: Martian Moons eXploration



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

→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**

PP evaluation of Mars knowledge gaps for robotic and human missions

Life Sciences in Space Research
Volume 36, February 2023, Pages 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]

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News & Views

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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]

The COSPAR planetary protection Policy for robotic missions to Mars

COSPAR
COMMITTEE ON SPACE RESEARCH

- In 2021, the Panel evaluated recent scientific data and literature regarding the planetary protection requirements for Mars and the implications of this on the guidelines. The group focused on three key areas:

1) Biocidal effects of the martian environment, 2) water stability, and 3) transport of spacecraft bioburden.

- These areas were discussed in the context of survival of dormant cells (where cells are either dormant or in a state of maintenance) vs proliferation (cells are actively defining) (National Academies of Sciences, Engineering, and Medicine. 2015; Rummel et al., 2014).

Life Sciences in Space Research 36 (2023) 27–35

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

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The COSPAR Panel on Planetary Protection will continue to work with the different national and international space agencies, the scientific community, and other stakeholders (e.g., the private sector and industry) to develop a roadmap for coordinating research activities addressing the identified knowledge gaps. This will include further characterisation of the biocidal effects at the surface of Mars, which needs to be addressed before *in-situ* reduction can be considered as an approach for bioburden control for robotic missions. Although the science underpinning the Policy is advancing, as highlighted in more recent reports (e.g. National Academies of Sciences, Engineering, and Medicine 2021, Spry et al. 2021) and in this paper, 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*

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

Mars Human exploration

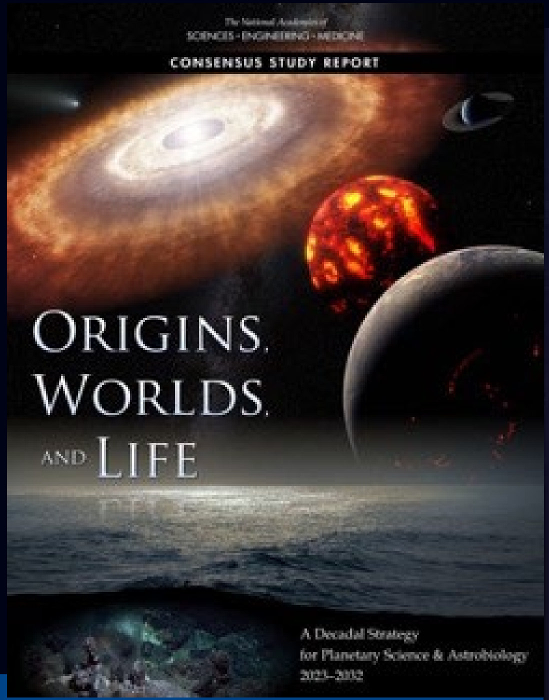
- These interdisciplinary meetings considered the next steps in addressing knowledge gaps for planetary protection in the context of future human missions to Mars. Reports from these workshops are posted under Conference Documents at https://sma.nasa.gov/sma-disciplines/planetary-protection/.
- The knowledge gaps addressed in this meeting series fall into three major themes: "*1. Microbial and human health monitoring; 2. Technology and operations for biological contamination control, and; 3. Natural transport of biological contamination on Mars." (Kminek et al., 2017)*
- 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.
- The approach was consistent with current scientific understanding and COSPAR policy, that the presence of a biological hazard in Martian material cannot be ruled out, and appropriate mitigations need to be in place. The findings were published in *Spry et al. (2024, Astrobiology, 24(3):230-274. doi: 10.1089/ast.2023.0092)* with COSPAR support. This paper highlights the scientific measurements and data needed for knowledge gap closure.

Current and future considerations

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

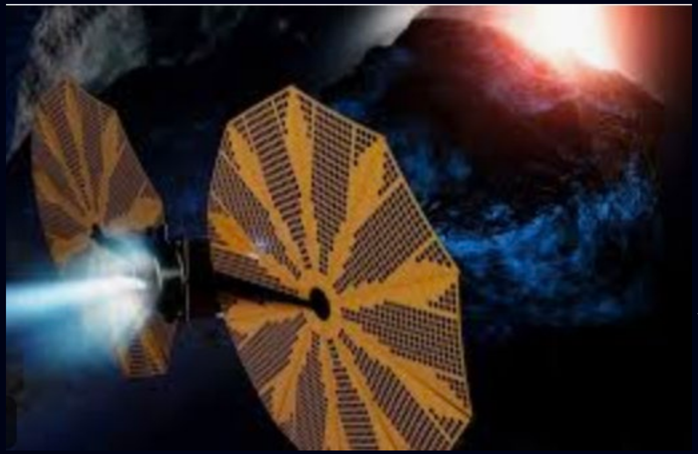
Some of these themes have been showcased in the NASEM OWL 2022 and ESA's Voyage 2050.

- 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



Mimas

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.
- 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. However, this classification is pending a written approval from the COSPAR Planetary Protection Panel in April. (collaboration with LASP (Colorado)

Hayabusa2

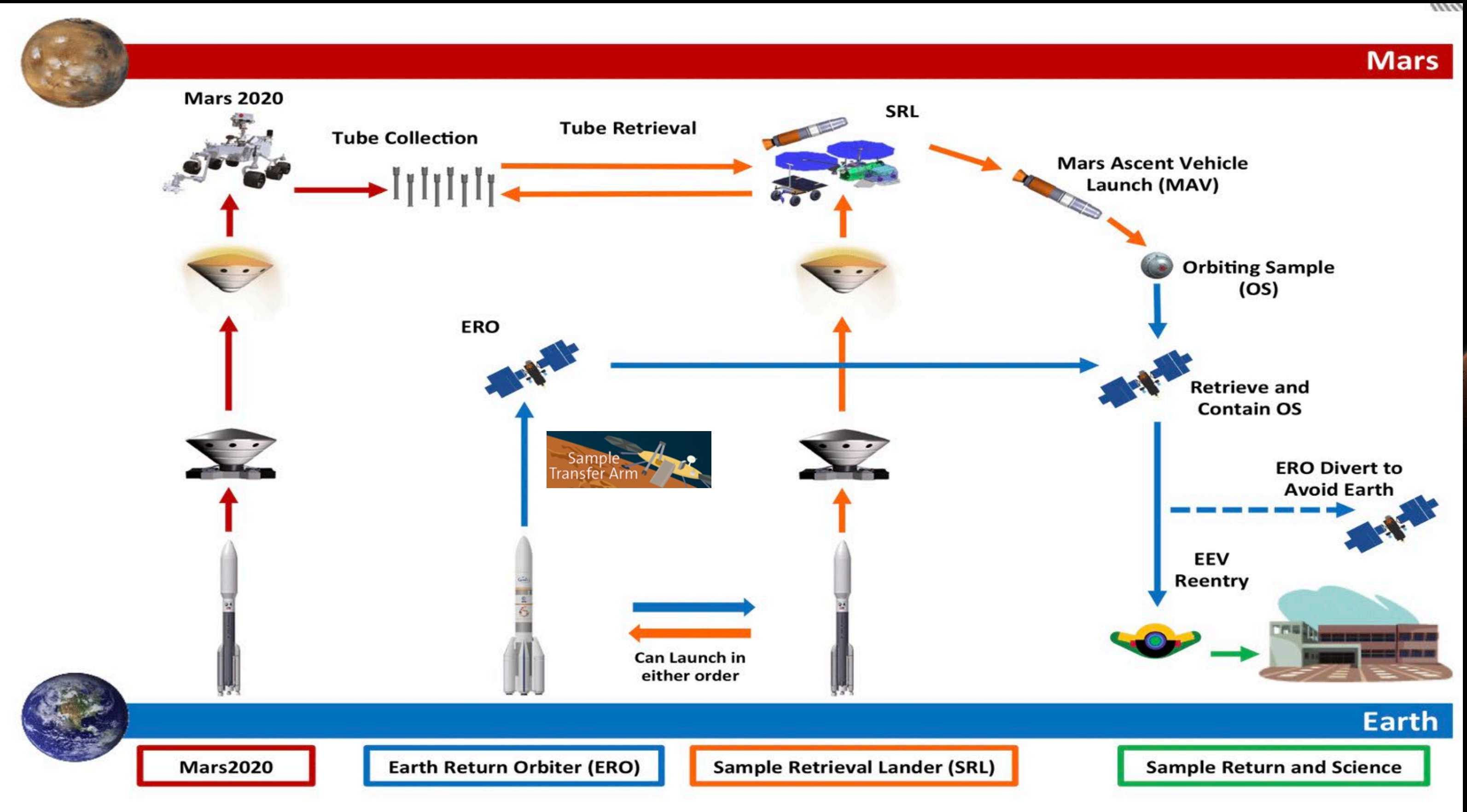
is a JAXA asteroid sample return mission . It was launched on 3 December 2014 and rendezvoused in space with near-Earth asteroid 162173 Ryugu on 27 June 2018. It surveyed the asteroid for a year and a half and took samples.

- 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 Hayabusa2# project manager contacted us to discuss the PP categorization proposal evaluation for the two asteroids they are targeting.
- Hayabusa2 will fly by asteroid (98943) 2001 CC21, "Torifune » in July 2026 and rendezvous with rapidly-rotating asteroid 1998 KY26 in July 2031.

PPP current Task Groups

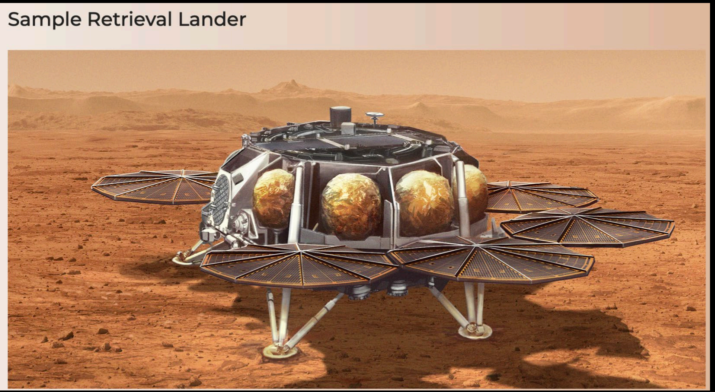
Subcommittee	Lead + Members
Moon subcommittee to work on lunar crewed mission/human missions Also recommend what we need add to the policy.	*Nick Benardini and Silvio Sinibaldi (Leads), P. Rettberg, A. Spry, E. Seasly, K. Olsson-Francis and M. Sefton*
Metagenomics subcommittee	*Nick Benardini (lead), Sinibaldi, Olsson-Francis, Lyle Whyte, Rettberg, Yohey Suzuki*
Icy Worlds subcommittee	*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*
COSPAR **Policy** Editorial updates	*Niklas Hedman (Lead) et al.*

NASA-ESA Mars generational exploration : the Mars Sample Return Campaign

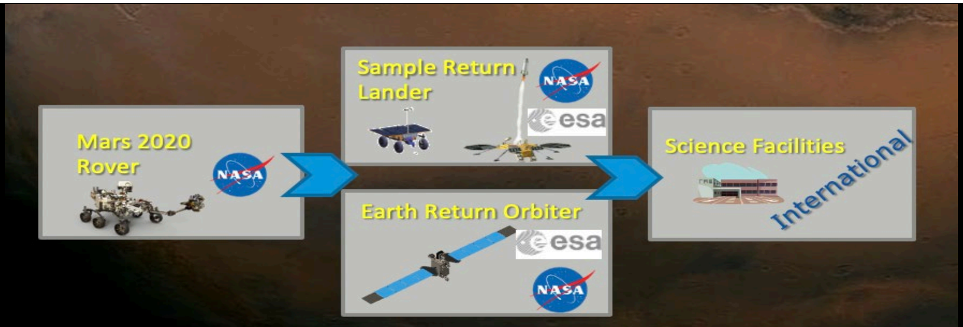


ERO

STA

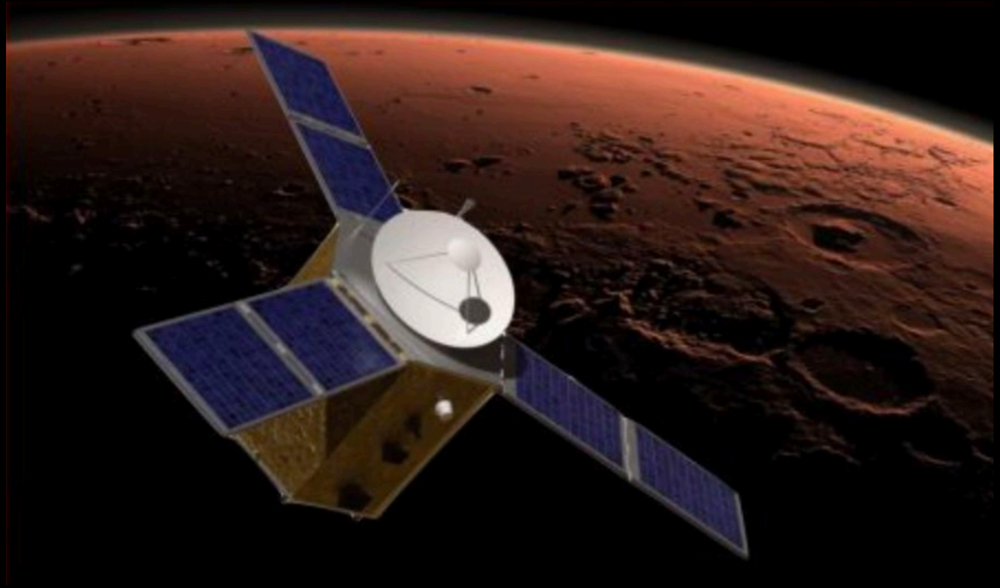


SRL



Strong collaboration between NASA and ESA

The ExoMars missions



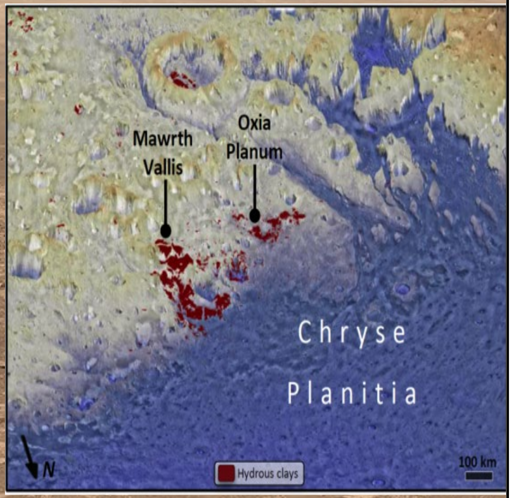
The ExoMars 2016
Trace Gas Orbiter (TGO)

The ExoMars 2028
Rosalind Franklin Rover

ESA ExoMars missions

Trace Gas Orbiter and the Rosalind Franklin

***2028 Rover :** searching for traces of past life*

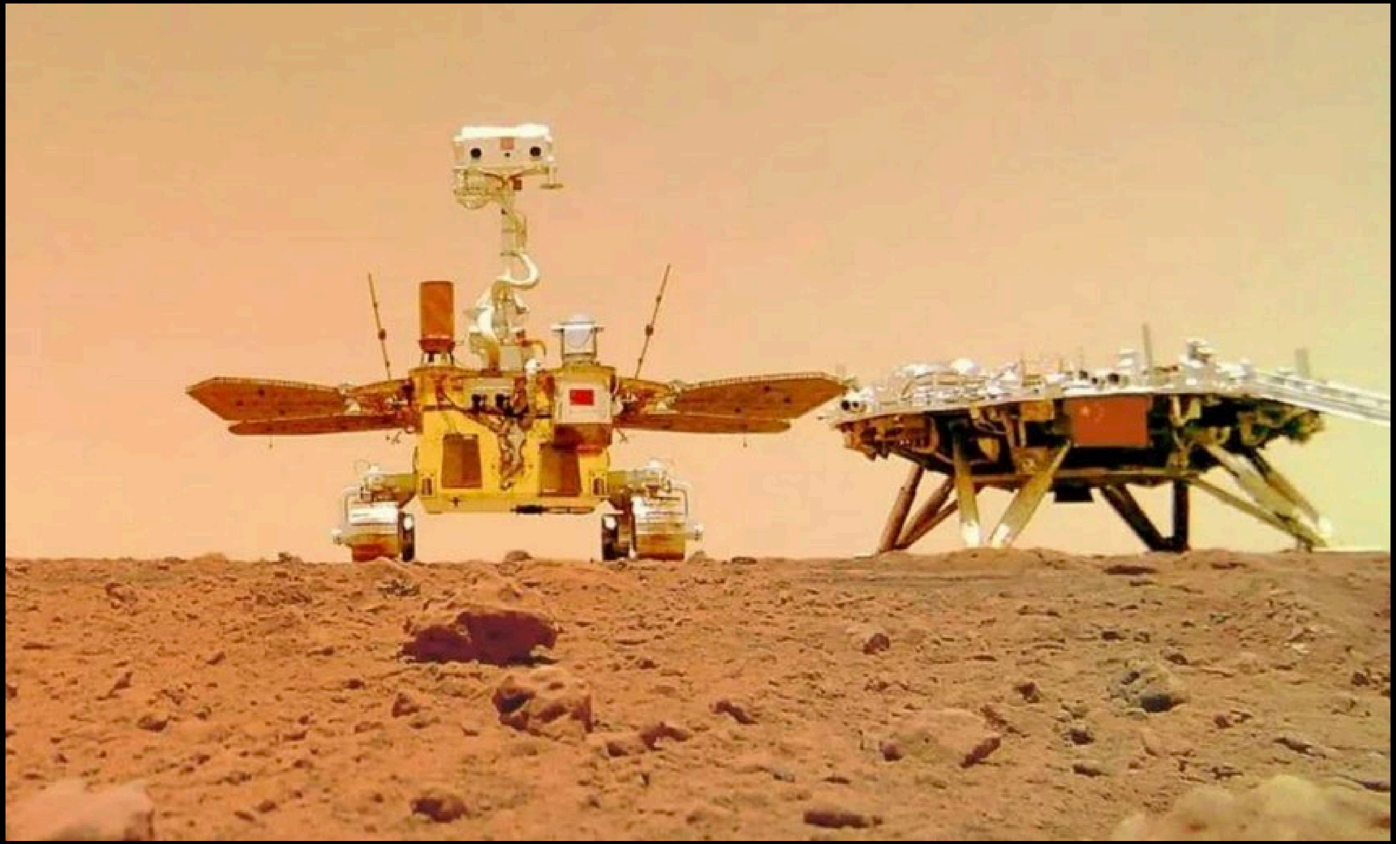


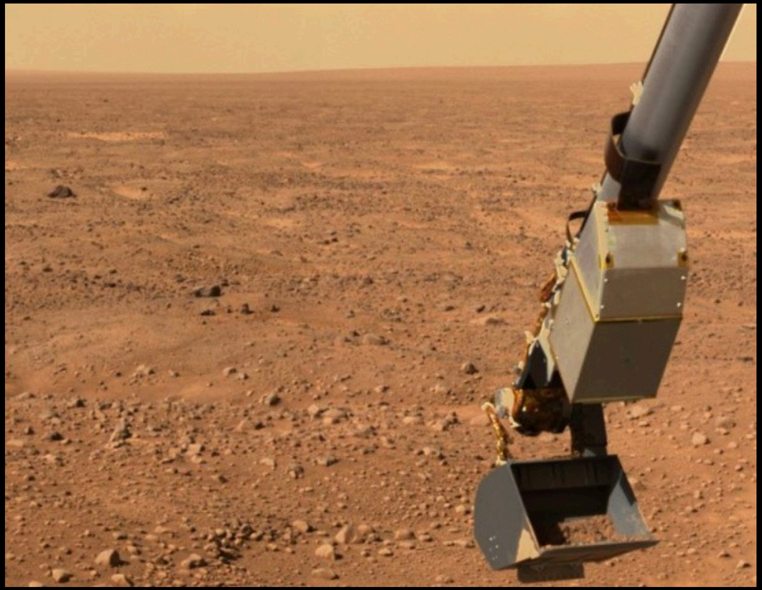
CAST : Tianwen-3 mission for Mars sample return

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

https://spacenews.com/china-unveils-planetary-exploration-roadmap-targeting-habitability-and-extraterrestrial-life/





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.

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

Planetary protection requirements for sample return from Mars : Cat V “Restricted Earth return”

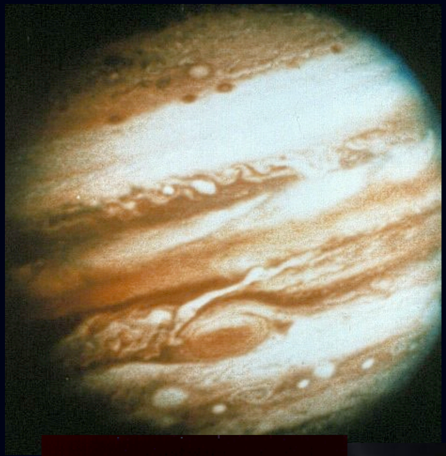
- Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements
- Unless the samples to be returned from Mars are subjected to an accepted and approved sterilization process, the canister(s) holding the samples returned from Mars shall be closed, with an appropriate verification process, and the samples shall remain contained during all mission phases through transport to a receiving facility where it (they) can be opened under containment
- The mission and the spacecraft design must provide a method to “break the chain of contact” with Mars, i.e. no uncontained hardware that contacted Mars, directly or indirectly, shall be returned to Earth
- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth re-entry.
- For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample

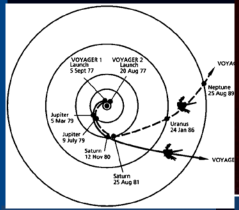
Icy Worlds
(not a cold case…)

Europa Clipper objectives

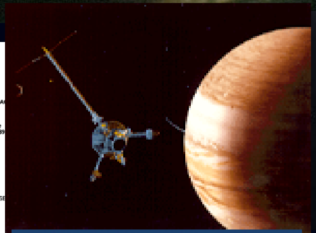
COSPAR
COMMITTEE ON SPACE RESEARCH

Giant planets and icy moons



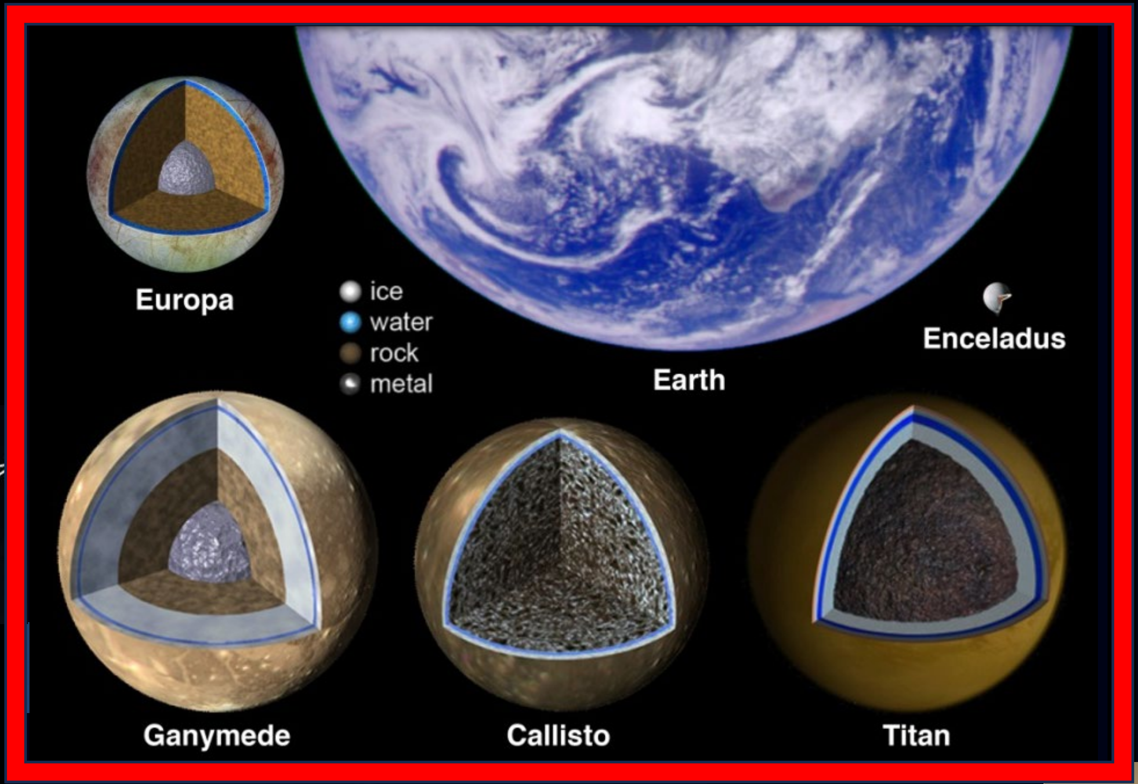


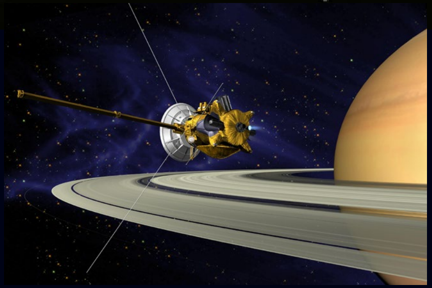
Voyager
1980s



Galileo
1995-2000

JUNO
2016-

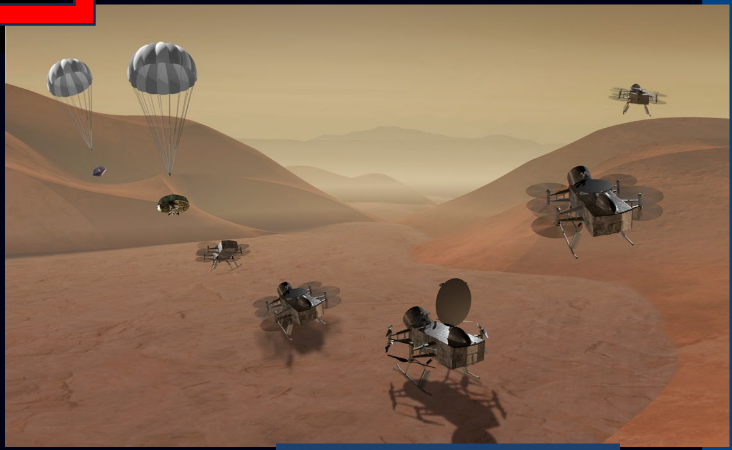




Cassini-Huygens
2004-2017

JUICE
Launched: April 2023

Europa Clipper
Launched Oct. 2024

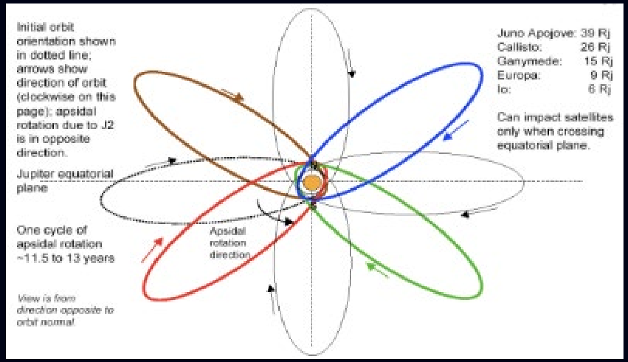


Dragonfly
Launch: 2028

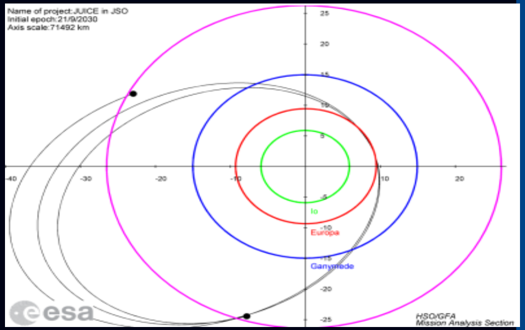
COSPAR
COMMITTEE ON SPACE RESEARCH

Planetary protection requirements Missions in the Jovian system

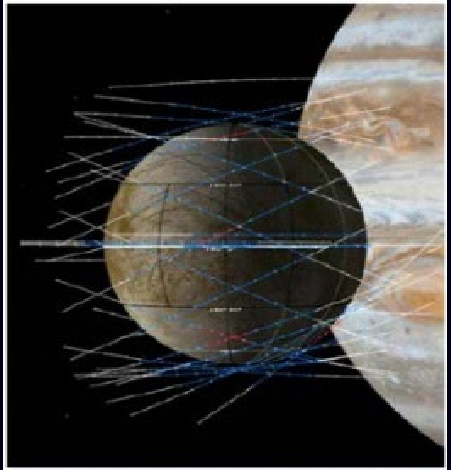
On site : JUNO: orbiter; main mission target is Jupiter; probabilistic risk assessment for final Jupiter de-orbit manoeuvre, assessment of sterilisation in natural Jovian environment, assessment of sterilisation during high velocity impact: Cat. II



En route (launched April 2023): JUICE: orbiter; main mission target is Ganymede, with 2 Europa fly-bys using Callisto transfers; reliability assessment for spacecraft failure, assessment of problematic species on flight hardware, assessment of sterilisation in natural Jovian environment : Cat. II* -> Cat. II *(see Grasset et al., 2013 and Tobie et al., 2025, PTA)*

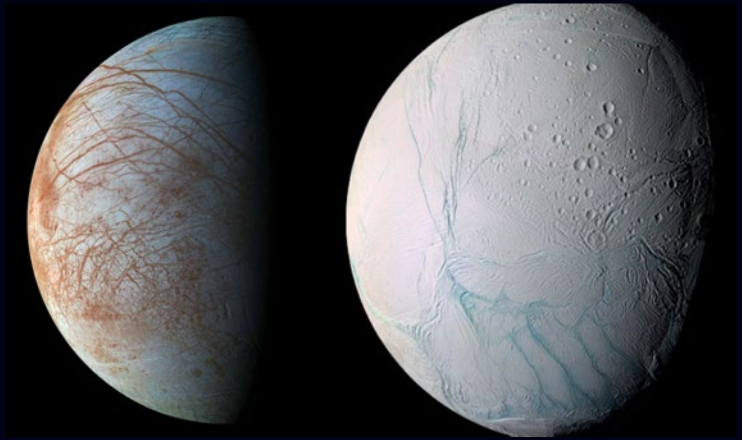


En route (launched Oct. 2024): EUROPA CLIPPER: orbiter; main mission target is Europa, with 45 Europa fly-bys; bioburden control of spacecraft before launch, assessment of sterilisation during flight : Cat. III



Planetary Protection of the Outer Solar System (PPOSS)

- Project led by the European Science Foundation, funded by the EC with DLR/Germany, INAF/Italy, Eurospace, Space Technology/Ireland, Imperial College London (UK), China Academy of Space Technology and NAS-SSB
- Recommended a revision of the planetary protection requirements for missions to Europa and Enceladus, based partly on the NAS-SSB 2012 Icy Bodies Report and on an ESA PPWG recommendation
- COSPAR was involved throughout the multi-year-long process and at the end updated the requirements for missions to Europa and Enceladus



Europa *Enceladus*

- *Policy should include a generic definition of the environmental conditions potentially allowing Earth organisms to replicate*
- *implementation guidelines should be more specific on relevant organisms*
- *implementation guidelines should be updated to reflect the period of biological exploration of Europa and Enceladus*
- *implementation guidelines should acknowledge the potential existence of Enhanced Downward Transport Zones at the surface of Europa and Enceladus.*

Published in

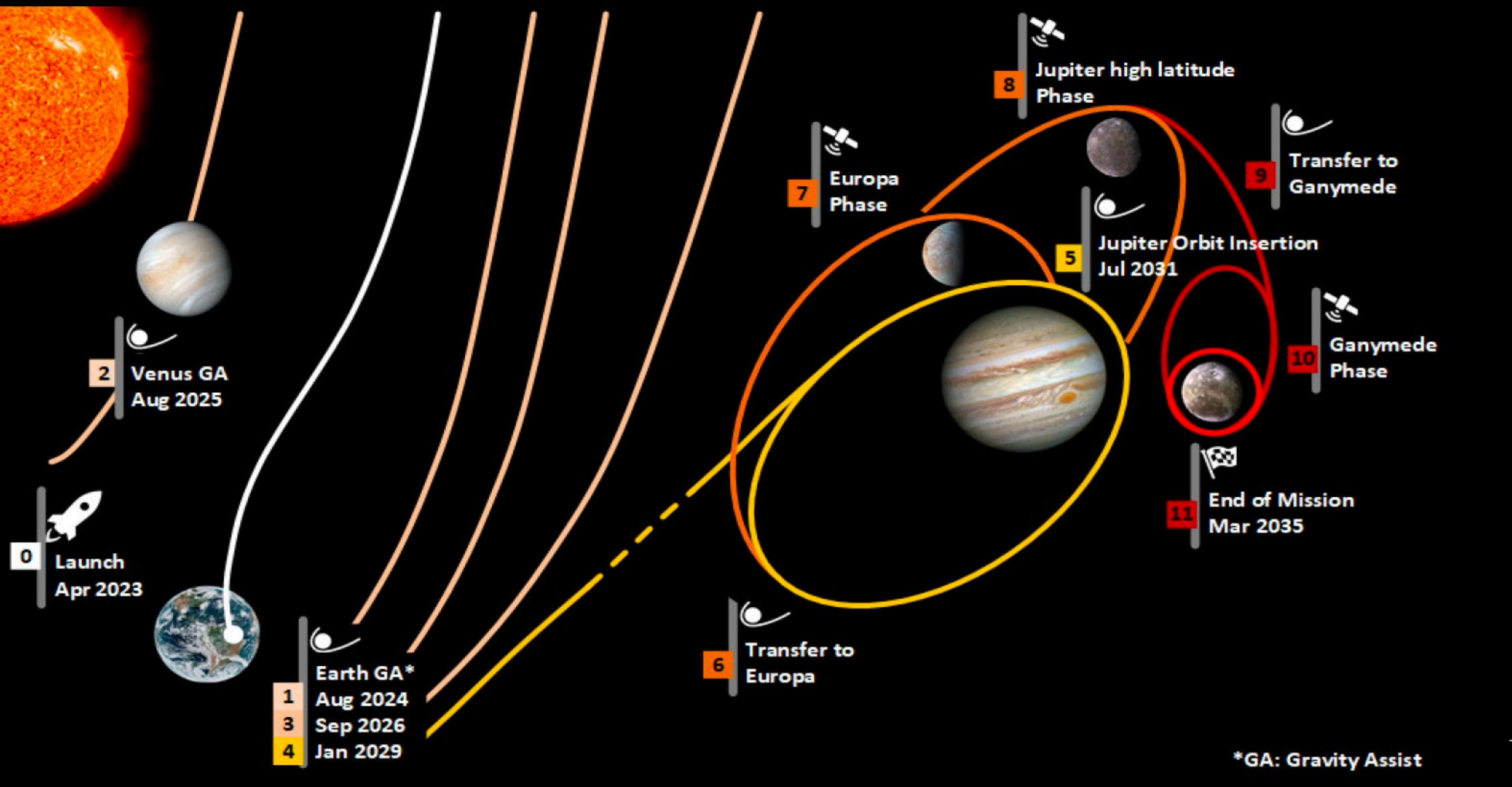
Space Res. Today (2020) 208

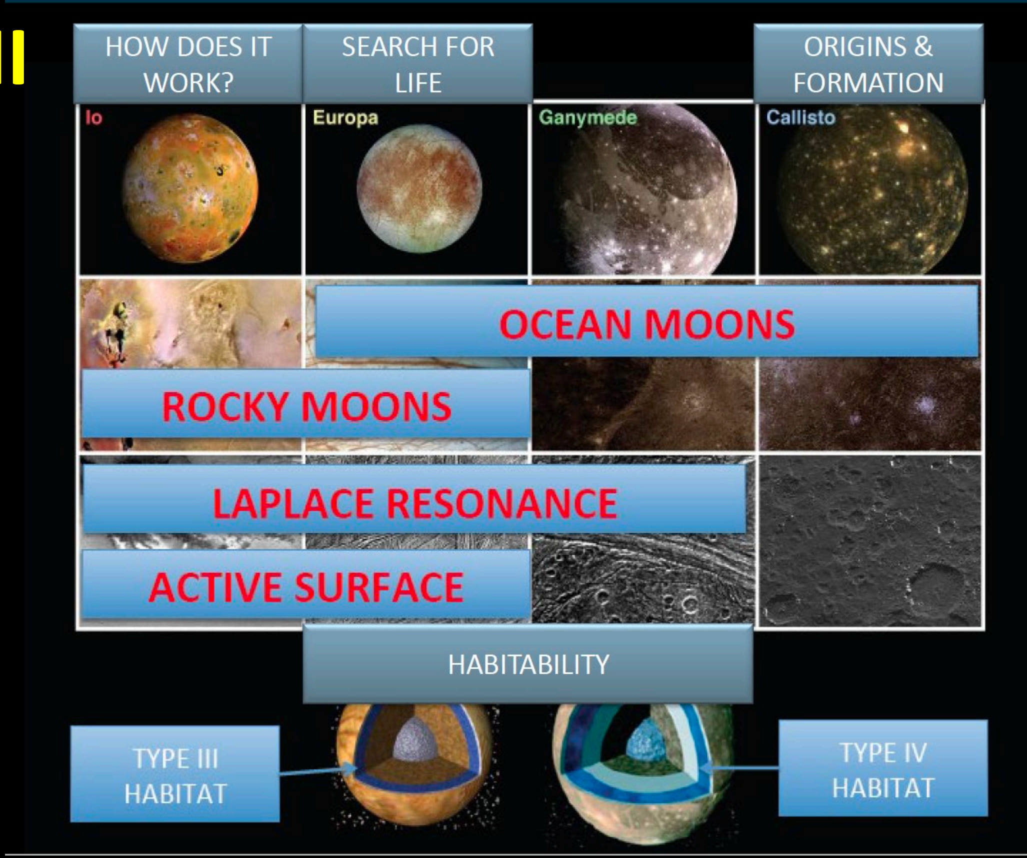
"Planetary protection: New aspects of policy and requirements", 2019.

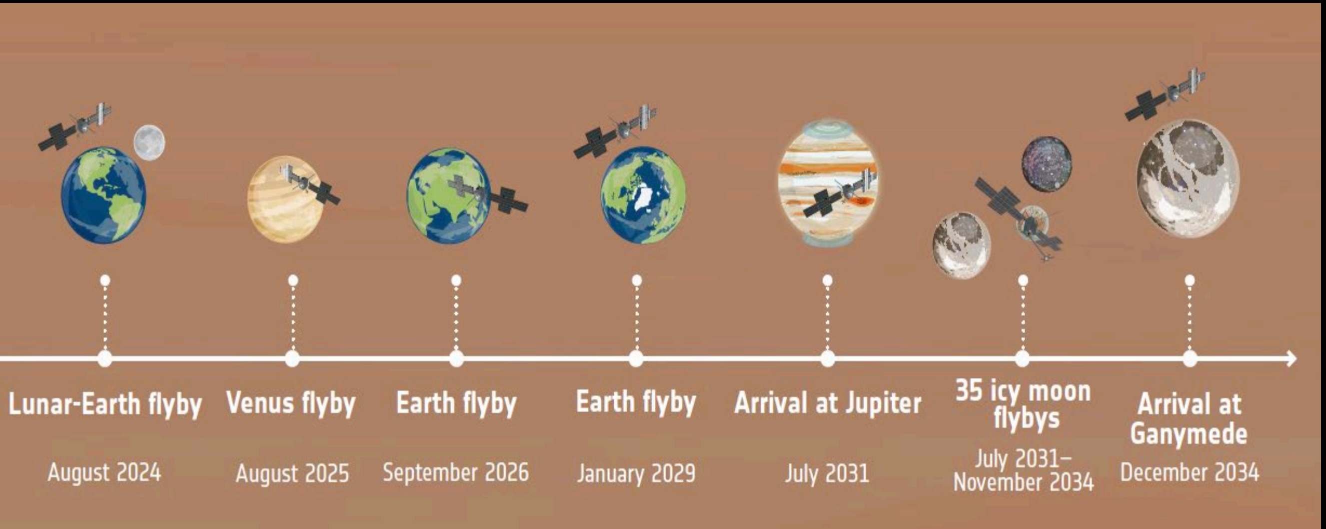
***Life Sci. Space Res.** 23*

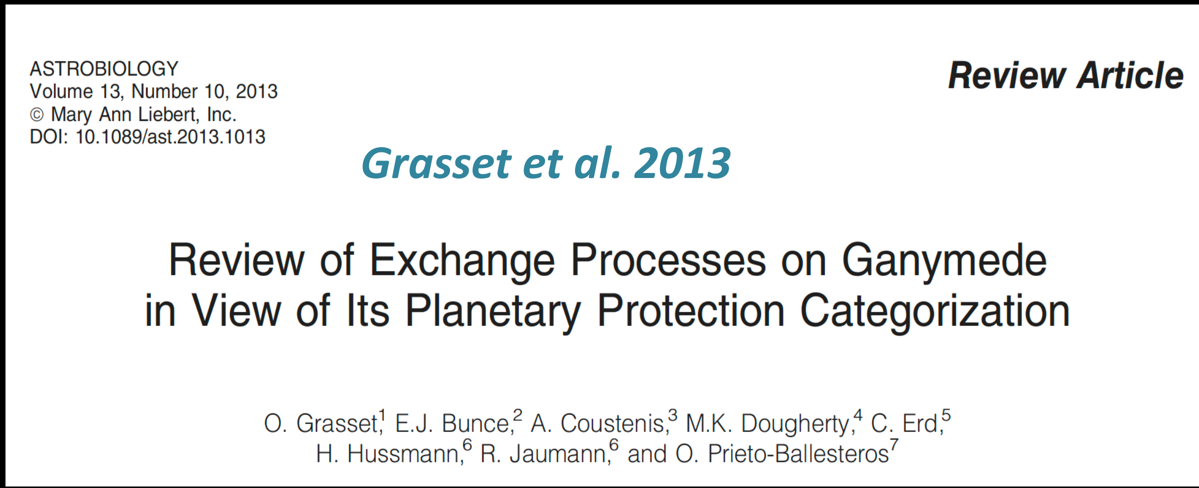
& The Internl PP Handbook: Dec. 2018

Categorisation of JUICE : Cat. II* -> Cat. II









ASTROBIOLOGY
Volume 13, Number 10, 2013

DOI: 10.1089/ast.2013.1013

Review Article

Grasset et al. 2013

Review of Exchange Processes on Ganymede in View of Its Planetary Protection Categorization

O. Grasset[1] E.J. Bunce,[2] A. Coustenis,[3] M.K. Dougherty,[4] C. Erd,[5]
H. Hussmann,[6] R. Jaumann,[6] and O. Prieto-Ballesteros[7]

Categorisation of JUICE

Requirements of Launcher Upper Stage – Mars

esa

The probability of impact on Mars by any element shall be $<10^{-4}$ for the first 50 years after launch (no parts assembled in ISO 8)

- Spacecraft: probability of impact is 5×10^{-5} until Jupiter orbit
- Launcher upper stage: no impact on Mars was simulated; 9.6×10^{-5} at 99% confidence limit

JUICE Planetary Protection Requirements – Europa

esa

Cat. III

Cat III: forward bioburden $<10^{-4}$ likelihood, demonstrated by accidental collision probability

Analysis by trajectory evolution analysis:

- Short term loss of control (failure during targeting)
  - Verify availability of redundancy
  - Navigate flyby by step-in target during approach
- Long term loss of control (during bound orbit around Jupiter, but before Ganymede orbit insertion):
  - Reliability and redundancy of spacecraft control equipment
  - Trajectory evolution after each planned manoeuvre, random loss of control – calculated the collision probability
  - Probability is 7.4×10^{-5}

Categorisation of JUICE

JUICE Planetary Protection Requirements – Ganymede

esa

Cat II+: no requirement placed, documented bioburden

- Sampling of cleanrooms, where JUICE was present over extended periods, including
- Airbus/Friedrichshafen integration room: 4 March 2019
- Airbus/Toulouse, Astrolabe, Pascal D: 9 Nov 2021 with JUICE present
- KSC S5A, CCU3, BAF-HE (encapsulation): 11 & 12 October 2021 – preparations and background with different satellite
- KSC S5C & S5A: 18 & 19 March 2023 with JUICE present
- ESTEC: part of nominal facility monitoring

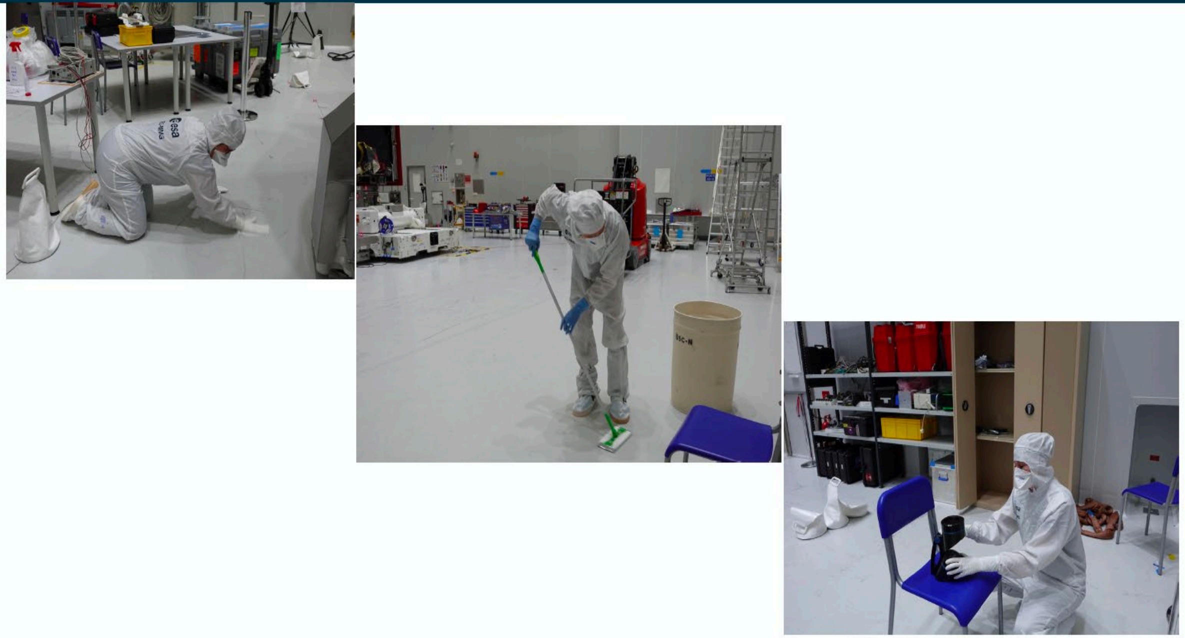
Cat. II* -> Cat. II

All planetary protection requirements are met for Cat. II

- Planetary Implementation and reports were reviewed and approved by ESA Planetary Protection Officer and Quality Control during all steps
- All spacecraft subsystems are fully operational after launch, no update of PP pre-launch documentation needed
- In addition, bioburden was sampled during all main assembly stages *Grasset et al. (2013) and Tobie et al. (2025)*

Bioburden Sampling in Kourou S5C

esa



Europa Clipper : Cat. III

Cat. III because the internal ocean is expected to be in contact with the satellite's silicate core, similarly to the case of our own planet, and the icy crust can be thin in some areas, called "chaotic". In 2002, the COSPAR Panel on Planetary Protection (PPP) had recommended the adoption of a simplified version of the Coleman-Sagan equation (Coleman and Sagan, 1965), which is used for establishing the probability of contaminating Europa by Earth microorganisms (NAP, 2000). It has also been suggested that the following factors must be quantified prior to any mission towards the outer system:

- **Bioburden at launch;**
- **Cruise survival for contaminating organisms;**
- **Organism survival in the radiation environment adjacent to the icy world;**
- **Probability of landing;**
- **The mechanisms and timescales of transport to the subsurface liquid water;**
- **Organism survival and proliferation before, during, and after subsurface transfer.**

Tobie et al. 2025, PTA 2025

McCoy et al. (2021) developed a probabilistic model considering various spacecraft failure scenarios and the associated potential for impact onto Europa, expected geological resurfacing timescales that could carry terrestrial biological contamination to Europa's liquid water; and assessment of biological mortality from Earth to Europa.

Taking into account these considerations, the estimate of the probability of Europa contamination, including probability of impact, resurfacing, and survival of microorganisms, is 2.25×10^{-5}, significantly below the contamination requirement (McCoy et al. 2021).

Using this risk assessment, the project showed that the probability is sufficiently small that Europa Clipper inadvertently impacts Europa and delivers hardware onto a piece of the surface that resurfaces within the 1000-year period of biological exploration

(McCoy et al. 2021, DiNicola et al. 2022, Pappalardo et al. 2024).

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.

Launch: 2028

Planetary Protection of Icy Worlds

COSPAR PPP Subcommittee (established in 2022)

(Chair: Peter Doran)
Alex Hayes, Olivier Grasset, Olga Prieto-Ballesteros,
Athena Coustenis, Kanyan Xu, Timothy Haltigin

Future exploration of Icy Worlds

After the PPOSS study (*The Internl PP Handbook (Dec. 2018) ; & "Planetary protection: New aspects of policy and requirements" (2019) in Life Sci. Space Res. 23 & Space Res. Today 208 (2020)*) a Panel subcommittee considered the future exploration of Icy Worlds and Ceres

The Panel has been working on a thorough review of the current knowledge for Icy Moons+Ocean Worlds (**Icy Worlds**: *"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."*) and is making proposals for a better coverage in the Policy

Findings were presented in different meetings and congresses and published

(Doran et al., 2024, LSSR, 41 pp. 86–99)

		Europa	Ganymede	Callisto	Enceladus	Titan	Mid-Size Saturnian Moons	Uranian Moons	Triton
WATER	Surface Liquid	✗	✗	✗	✗	✗	✗	✗	✗
	Subsurface Liquid	✓	✓	?	✓	✓	?	?	?
	Ground Ice	✓	✓	✓	✓	✓	✓	✓	✓
	Water Vapor				✓			?	?
CHEMISTRY	CHNOPS[1]	?			✓	✓	?	✓?	✓
	Complex Organics	✓			✓	✓			
ENERGY	Solar Heating	✗	✗	✗	✗	✗	✗	✗	✗
	Interior Heating[2]	✓	✓	✓	✓	✓	✓?	✓?	
	Redox[3]	?			✓	✓			
BODY	Atmosphere[4]	✗	✗	✗	✗	✓	✗	✗	✗
	Magnetic Field[5]	✗	✓	✗	✗	?	✗	?	✗
	Present Habitability	?	?	?	✓	?	?	?	?
	Past Habitability	?	?	?	?	?	?	?	?

✓ Yes/ Present ? Unknown/ Uncertain ✗ No/ Absent (hatched) Insufficient Information

[1]The life-supporting elements carbon, hydrogen, nitrogen, oxygen, phosphorus, or sulfur (not all need be present)
[2]Interior heating is that energy derived from accretion, differentiation, radiogenic decay, and/or tidal dissipation
[3]The prospect for any element or molecule to be reduced or oxidized as a source of chemical energy for life
[4]Subsantial atmospheres only; exospheres (formed by, e.g., impact sputtering) are not included
[5]Intrinsically generated magnetic fields only

Modified from NASEM Decadal. OWL, Courtesy of P. Byrne

We have since made several consultations and community outreach efforts for comments.

We have presented/discussed these aspects:

- 3 times to the CoPP
- COSPAR 2022 general assembly in Athens and 2024 in Busan
- OPAG in Fall 2023 and Spring 2024,
- LPSC meeting in March
- Inaugural Planetary Protection week in London, UK
- SBAG
- European Science Foundation

We have moved forward with a new publication and will discuss with the Panel members at our April Meeting in DLR

Subcommittee formed to review Icy Worlds in the PP policy.

PPP discussed review and ideas generated at last 3 meetings.

Resulted in a number of recommendations outlined in this paper

Life Sciences in Space Research 41 (2024) 86–99

Contents lists available at ScienceDirect

Life Sciences in Space Research

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

ELSEVIER

Check for updates

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]

Note 1: The paper discusses proposals for POTENTIAL changes to COSPAR PP policy for icy worlds

Note 2: As has been precedent, any eventual policy changes will not impact approved projects that are either already flying or in their final preparation stage

Missions to Icy Worlds (first set of findings)

COSPAR
COMMITTEE ON SPACE RESEARCH

After reviewing the current knowledge and the history of planetary protection considerations for Icy Worlds, the Panel subcommittee published its recommendations:

- 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 (These values are currently set at 0.5 and -28 ◦C and were originally established for defining Mars Special Regions)

Doran et al., 2024.

Life Sciences in Space Research 41 (2024) 86–99

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

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- Establish LLT as a parameter to assign categorization for Icy Worlds missions. The suggested categorization will have a 1000-year period of biological exploration, to be applied to all Icy Worlds and not just Europa and Enceladus as is currently the case.
- Have all missions 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 deeper environments where temperature is >LLT in the period of biological exploration.
- Restructure or remove Category II* from the policy as it becomes largely redundant with this new approach,
- Establish that any sample return from an Icy World should be Category V restricted Earth return.

New Definition for Icy Worlds in PP Policy

- The committee prefers “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

Proposed Definition:

“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, …

Ceres

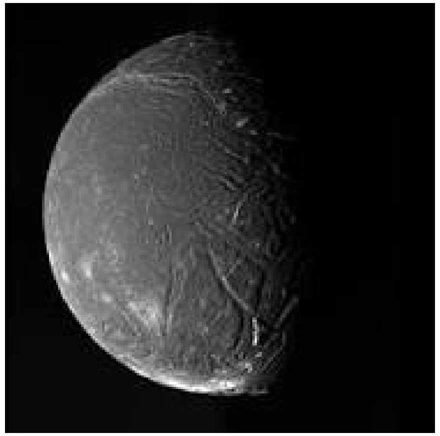
- After receiving community input, the panel is recommending to include Ceres in the list of Icy Worlds within the PP policy.

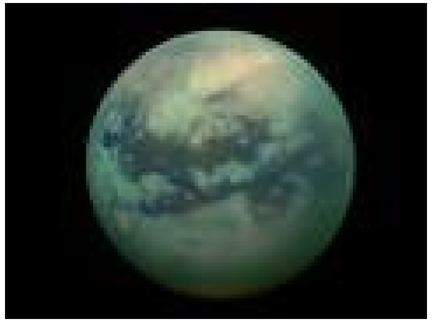
- While current knowledge suggests that there may be regions of interest on Ceres' surface / near-subsurface that may not be predominantly water ice (Kurokawa et al. 2020 ; McCord et al. 2022), <u>the general consensus is that Ceres is an ice-rich body with an outermost layer that is greater than 50% water ice by volume</u> (Park et al. 2020).

- There is also a recent review on our understanding of Ceres as it relates to Planetary Protection Policy for future landed missions, including for sample return, to the dwarf planet by Castillo et al. (2025).

- From a policy standpoint, including Ceres as an Icy World is a <u>conservative approach</u> as considering temperature alone, regardless of water activity, when identifying environments where terrestrial organisms may replicate is more restrictive.

- The guidelines for planetary protection categorization and compliance of flybys, orbiters, and landers targeting Ceres follows that of the Icy Worlds.





Body	Category	Current Classification
2002 MS_2	Dwarf Planet, Cubewano[1] (TNO)[2]	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*


[1] Classical Kuiper Belt Object
[2] Trans-Neptunian Object

COSPAR POLICY ON PLANETARY PROTECTION

Prepared by the COSPAR Panel on Planetary Protection and approved by the COSPAR Bureau on 3 June 2021.

Based on a recommendation by PPOSS

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:

– Lower limit for water activity: 0.5
– Lower limit for temperature: -28˚C

WHERE DID THESE NUMBERS COME FROM?

Mars Special Regions

Concept of Special Regions developed qualitatively by COSPAR and adopted in PP policy in 2002

"A region within which terrestrial organisms are likely to propagate, or a region which is interpreted to have a high potential for the existence of extant martian life forms."

As guidelines to identify Special Regions on Mars, it is stated that:

"Given current understanding, this applies to regions where liquid water is present or may occur. "

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 2015)	-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^{o}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^{o}C 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^{o}C
- There is a well documented cryoecosystem on Earth in relatively warm ice.

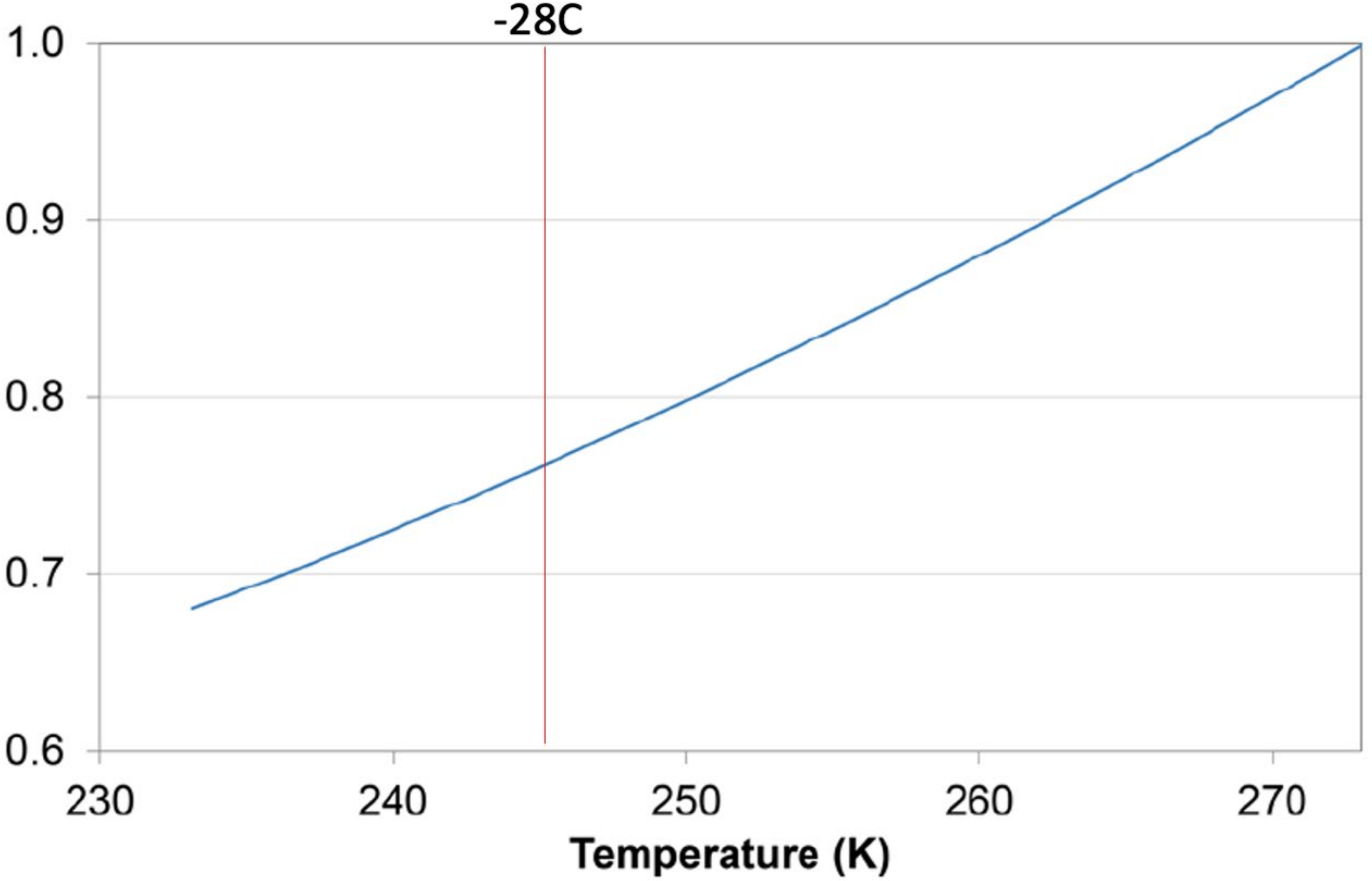
Where there's water there's life?

- Exception on Earth is almost always associated with brines with high salinity/low water activity.
- These brines can also be liquid, or be a mixture of ice/liquid down to very cold temperatures (<-40C)

$CaCl_2$ in Don Juan Pond, Antarctica

$MgCl_2$ in Lake Gounter, Western Australia

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)

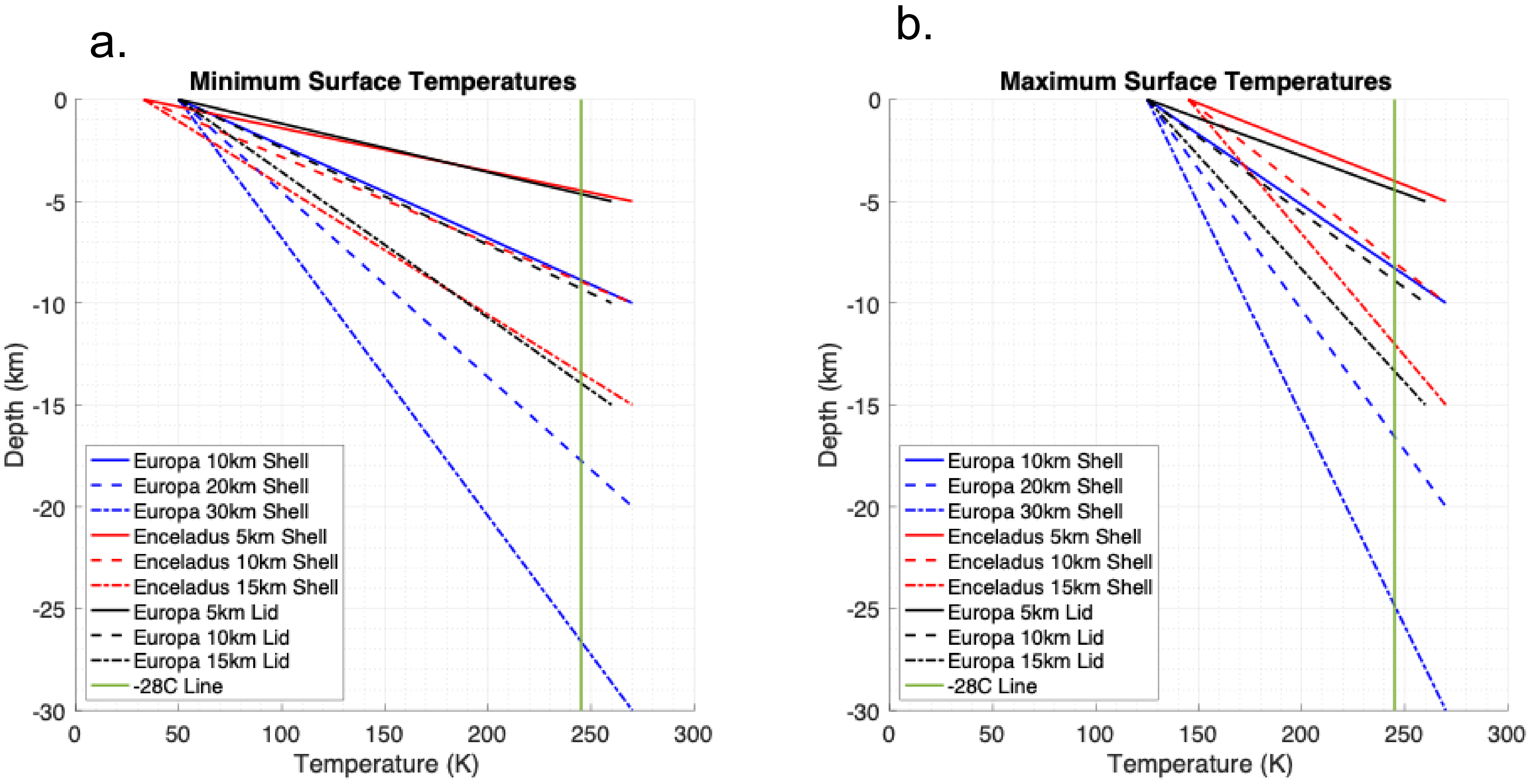
- Ganymede (Jupiter) internal ocean ~3 X larger than Europa, but lacks clear evidence of a connection
  T_{surf}=-113^{o}C (midday at equator, colder toward poles / other times)

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

- Callisto (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

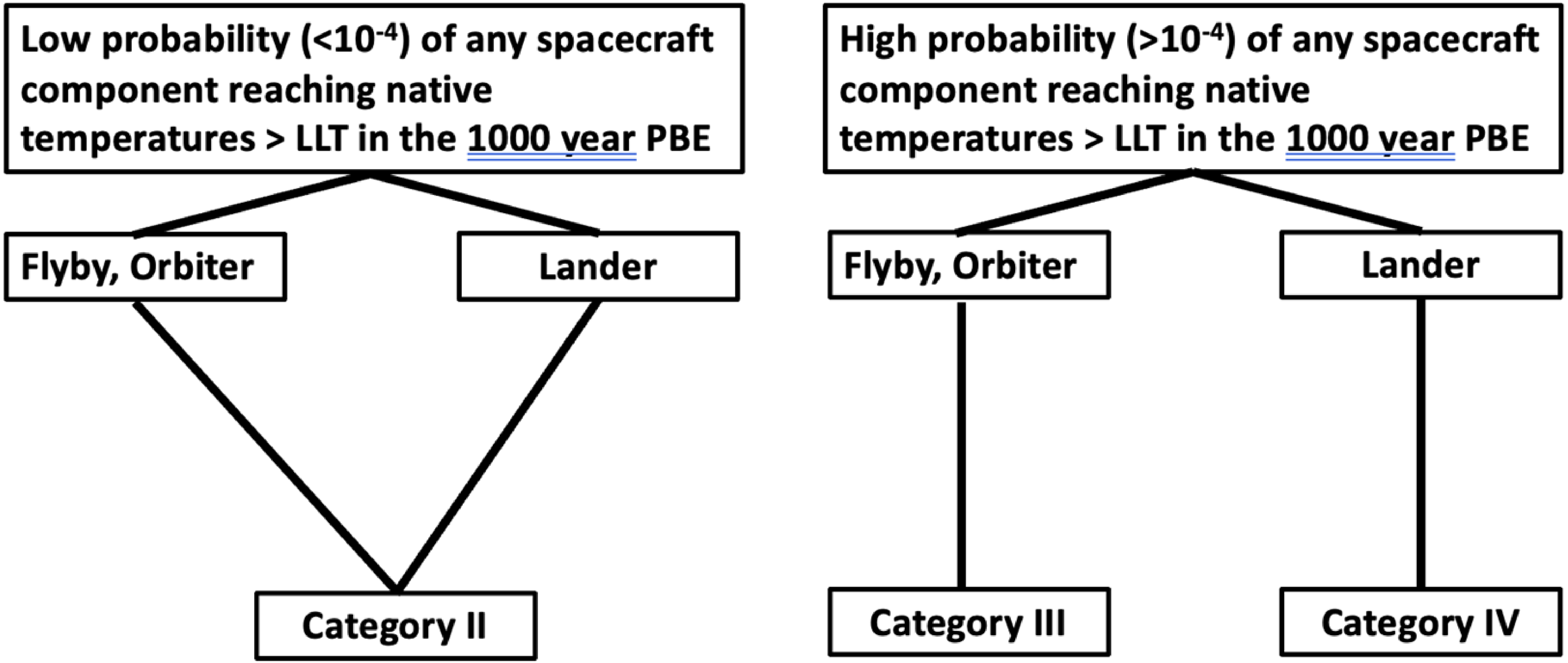
THIS IS JUST AN EXAMPLE OF THE TYPE OF MODELING A MISSION MIGHT USE



"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)"

Doran et al. 2024

Missions to Icy Worlds are categorized based on the likelihood that the spacecraft will connect with temperatures >-28C (LLT) within 1000 years (PBE).



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

Where did those numbers come from?

10^{-4}

The 10^{-4} contamination criterion can be traced back to a COSPAR resolution from 1964, but no record of the rationale for adoption of it. NRC (2012) concludes that 10^{-4} was appropriate to apply to Europa, even though it was first adopted for Mars and that the standard is appropriately conservative and implementable

1000 years

NRC (2012) argued that clearly since the first planetary space probes were then around 50 years old and space exploration is still in its infancy, that 50 years or even 100 years is too little time. They further argued that the speed at which technology evolves and the duration of human civilizations do not offer a solid rationale for implementing a period of planetary protection lasting 10,000 years or beyond.

NRC, 2012. Assessment of Planetary Protection Requirements for Spacecraft Missions to Icy Solar System Bodies. Washington, DC: The National Academies Press. https://doi.org/10.17226/13401.

Sample return questions derived from NRC (1998) and currently in policy for "Sample Return from Small Solar System Bodies" *(they should be adapted for Icy Worlds)*

For containment procedures to be necessary, an answer of "no" or "uncertain" needs to be returned to 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.

Conclusions and way forward for Icy Worlds

- 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°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 if 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. 2025, Phil. Trans. A, in review)*

COSPAR
COMMITTEE ON
SPACE RESEARCH

The COSPAR PP Policy
(a living document…)

The COSPAR PP Policy: a living document

COSPAR
COMMITTEE ON SPACE RESEARCH

Objective was to enhance the understanding and clarity of the Policy and associated guidelines for consistency and transparency, including by introducing a more objectives-driven and case-assured (vs. prescriptive) approach to the formulation and implementation of planetary protection controls.

- Clarifying the status of the Policy as a non-legally binding international standard; quoting both OST Article VI and IX.
- New chapters clarifying the role and function of COSPAR PPP; presenting key assumptions that form the basis for the technical guidelines; listing categorization considerations to capture the rationale and intent behind the categorization process.
- Restructuring the Policy and associated guidelines with explanatory text. including graphics/tables on a) Planetary protection process overview (categorization and corresponding guidelines); b) Planetary protection categories in relation to target bodies; c) Guideline specification; d) Example of expected elements for mission documentation.

New Policy
Published In SRT 220, 12 July 2024

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.

Future PPP meetings

International COSPAR Planetary Protection Meeting :

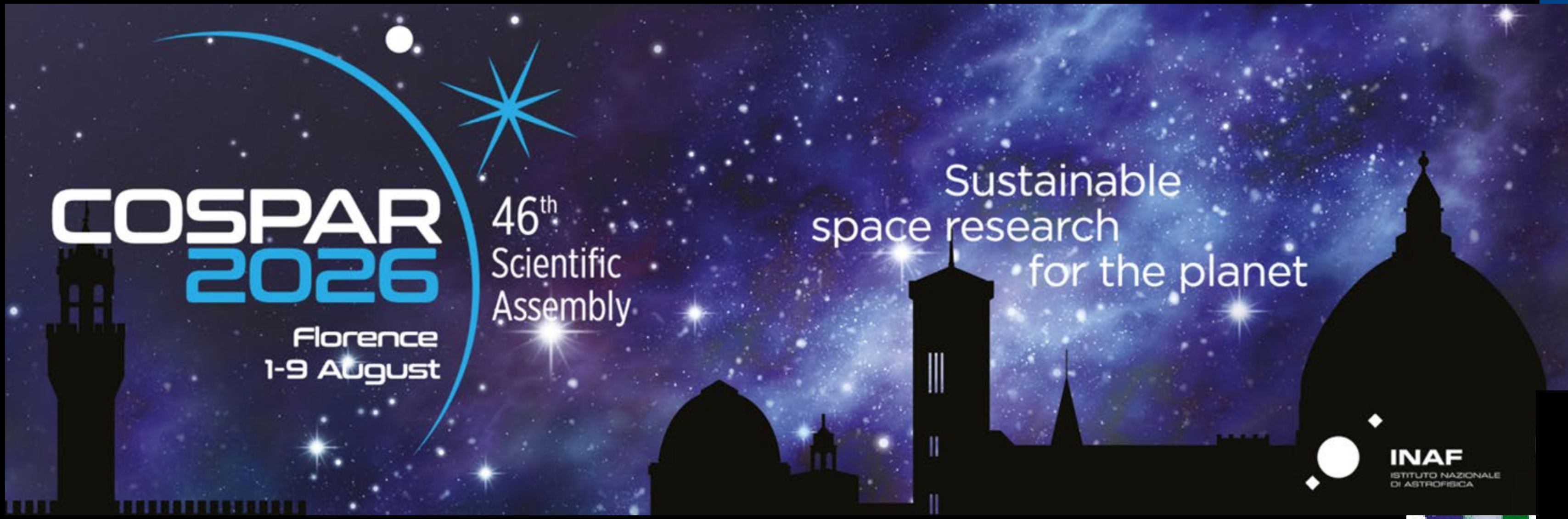
14-16 April 2025, DLR/Cologne, Germany

Register for the Open sessions : https://cosparhq.cnes.fr/scientific-structure/panels/panel-on-planetary-protection-ppp/

COSPAR Symposium,3-7 Nov. 2025, Nicosia, Cyprus
https://www.cospar-assembly.org/symposia/

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

COSPAR SYMPOSIUM 2025
3-7 November, NICOSIA



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**