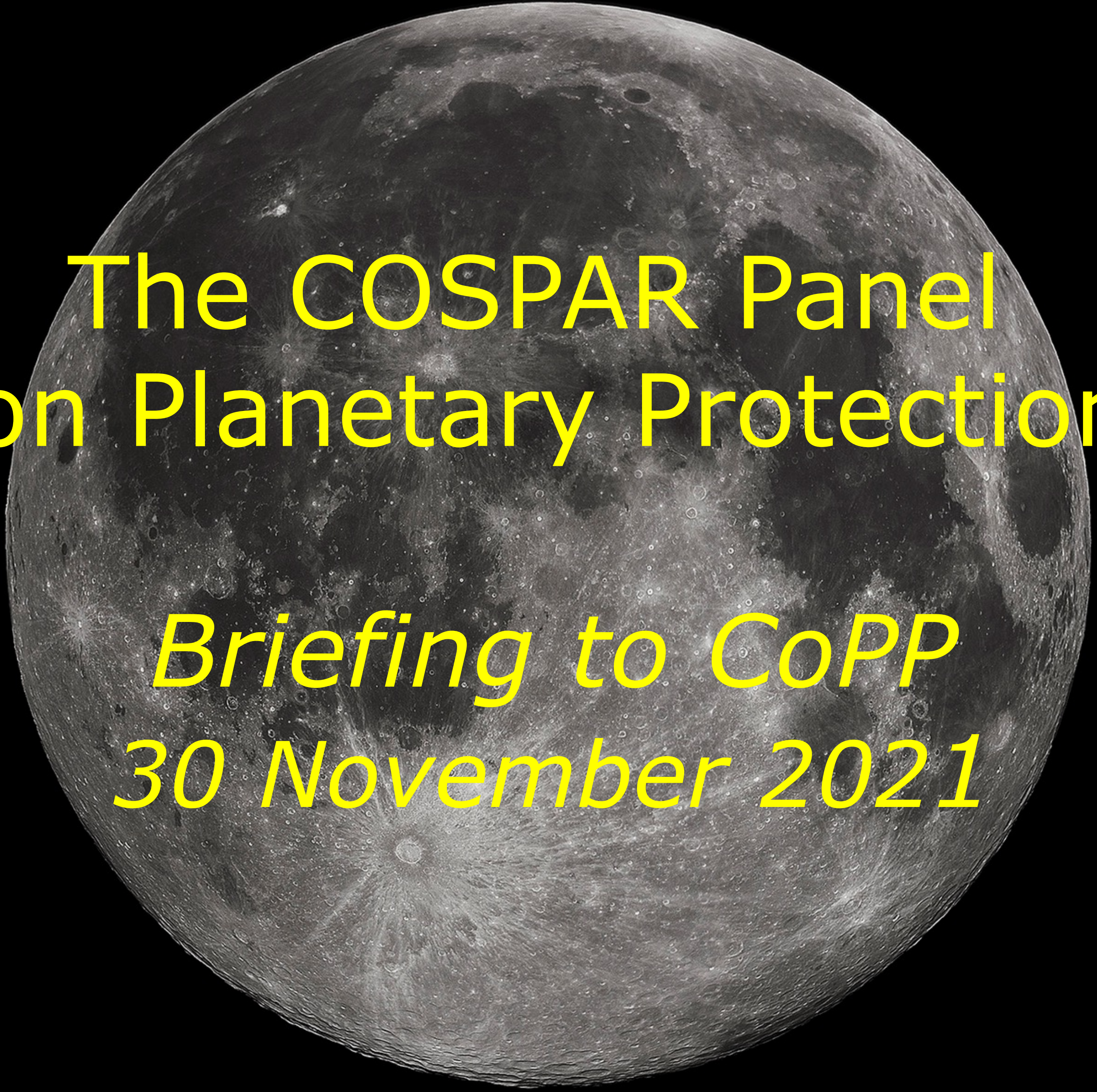


The COSPAR Panel on Planetary Protection

Briefing to CoPP

30 November 2021

COSPAR planetary protection 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 110 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.

Panel on Planetary Protection Membership

Chair:

– **Athena Coustenis** (LESIA, Paris Observatory, CNRS, Meudon, France), planetology

Vice-Chairs:

– **Niklas Hedman** (UNOOSA, Vienna, Austria), space law
– **Gerhard Kminek** (European Space Agency, Noordwijk, NL), Earth sciences

10 Members Appointed by Space Agencies:

– **Eleonora Ammannito** (Italian Space Agency, Rome, Italy), planetology
– **Masaki Fujimoto** (JAXA/ISAS, Kanagawa, Japan), space plasma physics
– **Sarah Gallagher** (Canadian Space Agency), X-ray astronomy
- **Sarah Gallagher** (Canadian Space Agency, X-ray astronomy)
– **James Green** (NASA, Washington, DC, USA), plasma physics, astrobiology
– **Praveen Kumar Kuttanpillai** (ISRO, Bengaluru, India), engineering scientist
– **Christian Mustin** (Centre National des Etudes Spatiales, Paris, FR), astrobiology
– **Karen Olsson-Francis** (UKSA, Swindon, UK), astrobiology, microbiology
– **Jing Peng** (China National Space Administration, Beijing, China), engineering
– **Petra Rettberg** (DLR, Cologne, Germany), microbiology, astrobiology

Member Ex-officio:

– **Colleen Hartman** (Director Space Studies Board, Board on Physics and Astronomy, US National Academies of Sciences, Engineering, and Medecine)

10 Scientists /Experts

– **Peter Doran** (Dept. of Geology and Geophysics, Louisiana State Univ., Baton Rouge, LA, USA), hydrogeology, Extreme Environments
– **Olivier Grasset** (Nantes Univ., Nantes, France), geodynamics, planetology
– **Alex Hayes** (Cornell Univ., Ithaca, NY, USA), planetology
– **Viacheslav Ilyin** (Russian Federation State Research Center Institute for Biomedical Programs, Russian Academy of Sciences, Moscow, Russia), microbiology, medecine
– **Akiko Nakamura** (Dept. of Planetology, Graduate School of Science, Kobe Univ., Nada, Kobe, Japan), experimental physics
– **Olga Prieto-Ballesteros** (Dept. of Planetology and Habitability, Centro de Astrobiologica, Torrejon de Ardoz, Madrid, Spain), geology, astrobiology
– **François Raulin** (LISA, Univ. Paris Est, CNRS, Univ. Paris, PSL, Créteil, France), chemistry, planetology
– **Kanyan Xu** (Laboratory of Space Microbiology, Shenzhou Space Biotechnology Group, Chinese Academy of Space Technology, Beijing, China), microbiology, biochemistry
– **Maxim Zaitsev** (Planetary Physics Dept., Space Research Inst. of Russian Acad. of Sciences, Moscow, Russia), astrochemistry, organic chemistry
– **Maria-Paz Zorzano Mier** (Centro de Astrobiologica, Torrejon de Ardoz, Madrid, Spain), astrobiology, biophysics

Scope and Objectives of the COSPAR Panel on Planetary Protection

- 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 UN Outer Space Treaty.

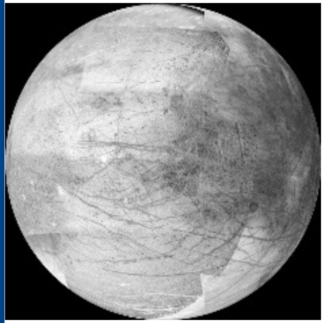
- The Panel provides, through workshops and meetings also at COSPAR Assemblies, an international forum for the exchange of information on the best practices for adhering to the COSPAR planetary protection requirements. Through COSPAR the Panel informs the international community, including holding an active dialogue also with the private sector.

- Since its restructuring in mid-2018, the Panel has had **9 full meetings** (July 2018; Jan. & Dec. 2019, June & Nov. 2020, Jan. 2021 @ the COSPAR GA, 15 Feb., 18 May & 20 Oct 2021…) and about 30 telecons between PPP Leads and parts of the Panel & COSPAR Leads.
- COSPAR is constantly reviewing its Policy in view of recent scientific findings and needs.

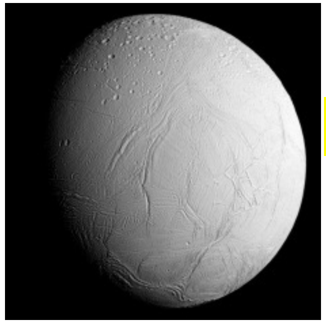
The COSPAR Panel on Planetary Protection:
https://cosparhq.cnes.fr/scientific-structure/ppp

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
- The ESA PPWG submitted a written assessment of the PPOSS recommendation to COSPAR
- COSPAR was involved throughout the multi-year-long process and at the end updated the requirements for missions to Europa and Enceladus



Credit: NASA/JPL/Galileo



Credit: NASA/JPL/Cassini

Published in Space Res. Today *208, 10-22 (Aug. 2020)*

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

Life Sci. Space Res. *23*

The Internl PP Handbook: Dec. 2018

Martian Moon Explorer (MMX)

In 2019 ESA and JAXA studied sample return missions from Martian moons Phobos and Deimos

- ESA, NASA and JAXA supported scientific activities 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, followed by an independent review by the NAS-ESF
- Outcome was presented to the ESA Planetary Working Group (PPWG) and to COSPAR, involved from the beginning
- assigned planetary protection category for the MMX mission : outbound Cat III and inbound Cat V: unrestricted Earth return)

Updated planetary protection for the Moon

Resulting from literature, COSPAR & LEAG surveys, studies and PPP meetings in 2020 and 2021.
In particular, the **CoPP report** *"Planetary Protection for the Study of Lunar Volatiles " (2020)*

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

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

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.

COSPAR Panel on Planetary Protection
Plenary Meeting Agenda : *20 October 2021*

OPEN SESSION

(More than 40 participants)

13:00 Introduction and purpose of the meeting - *(A. Coustenis)*
13:10-13:20 COSPAR items & introduction of new members - *(J-C. Worms)*
13:20-13:45 Information points/activity report since the last meeting - *(PPP Leads)*
13:45-15:00 Briefings from agency representatives - *(e.g. J. Green, N. Benardini)*
15:00-15:00 Other briefings from observers/ invited guests - *(TBA)*

15:10-16:00 Status on Venus exploration PP-related matters and discussion
16:00-17:00 Status on Mars exploration PP-related matters and discussion
- Briefing from the NASEM/CoPP - *(J. Alexander & A. Hendrix)*
- Mars Program from the European side - *(G. Kminek)*

CLOSED SESSION

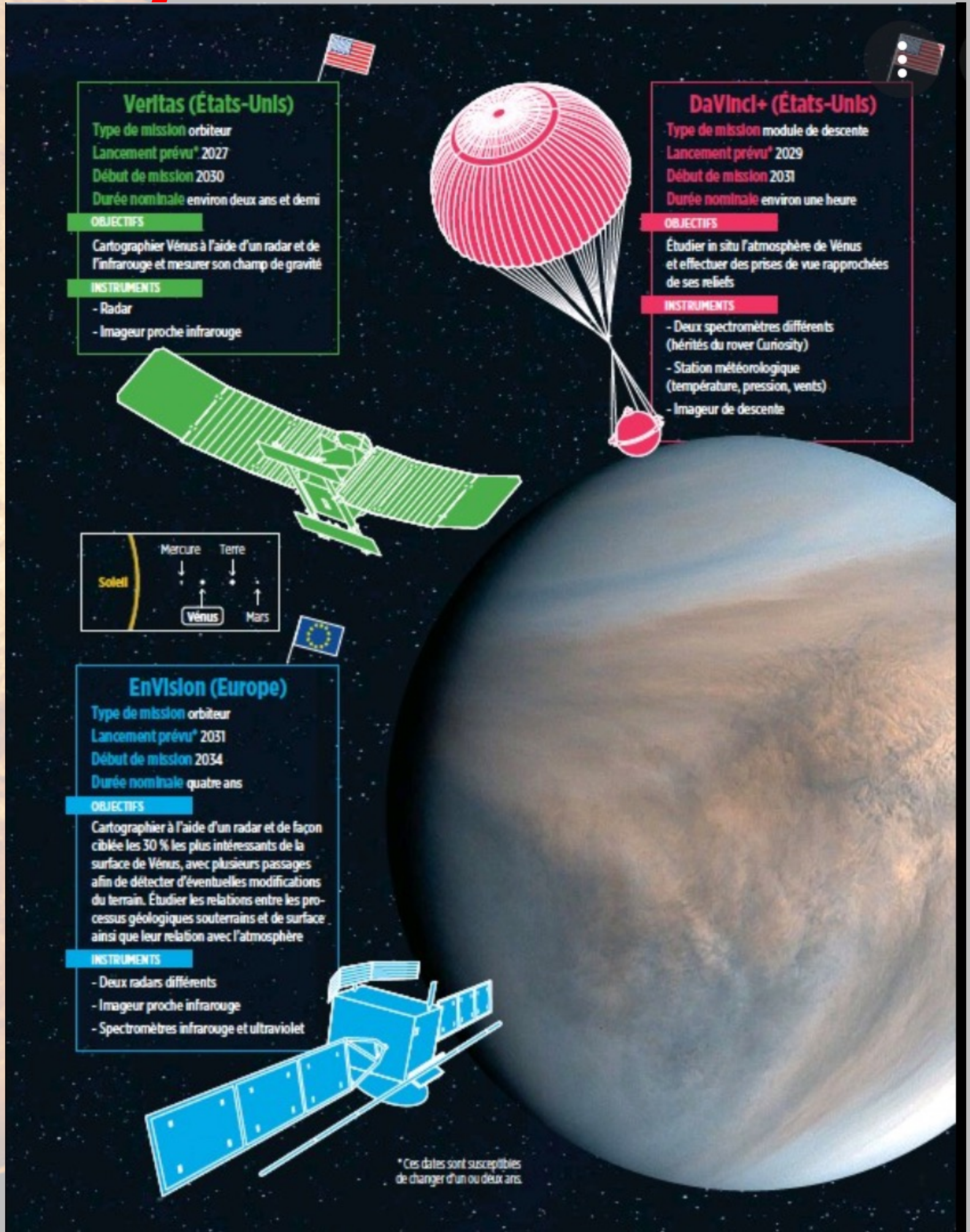
17:30 Executive session *(members only)*

Venus habitability?

- <u>Finding:</u> **Based on the existing measurements VENUS CLOUDS ARE NOT SPECIAL REGIONS.** Due to the low level of water in the clouds where the temperatures are mild enough, life as we know, would not be able to replicate there even if there were nutrients available (and protection from radiation, sulfuric acid etc).
- <u>Recommendation:</u> **unless there are new measurements that demonstrate water activity > 0.6 (RH> 60%), Venus clouds are not a concern for planetary protection.** They are of course extremely interesting for planetary science, including atmospheric chemistry, P cycle, etc.

Hallsworth et al., 2021 : Nature Astronomy

Venus, poses no concern for planetary protection ...because "*life as we know*" from Earth would not proliferate there.



See the COSPAR PPP website for more information

MARS

Mars Special Regions

Planetary Protection

Introduction of Mars Special Regions into COSPAR Planetary Protection Policy, 2002
- Mars Special Regions discussed in the COSPAR Planetary Protection Panel, Warsaw, July 2000

Review & Update of Mars Special Regions, 2008
- NRC Preventing the Forward Contamination of Mars, 2006
- MEPAG Mars Special Regions Science Analysis Group, SR-SAG, 2006
- COSPAR Colloquium on Mars Special Regions, Rome, Sept. 2007

Review & Update of Mars Special Regions, 2017
- MEPAG Mars Special Regions Science Analysis Group 2, SR-SAG2, 2013-2014
- COSPAR Workshop on Mars Special Regions, Montreal, April 2014
- NRC-ESF Committee to review SR-SAG2, 2014-2015 (NAP Report, 2015)
- COSPAR Planetary Protection Colloquium, Bern, Sept. 2015

The reviews & updates were presented and discussed at least once at the NASA Planetary Protection Sub-Committee and the ESA Planetary Protection Working Group.

Third report of the Space Studies Board ***Committee on Planetary Protection*** released on October 7, 2021. See: Space Studies Board website: https://www.nationalacademies.org/ssb/space-studies-board.

Presented and discussed at the PPP on 20 October 2021 and consideration in progress.

First COSPAR PPP comments on the CoPP report: "Evaluation of Bioburden Requirements for Mars Missions"

A PPP subcommittee was formed to comment on some of the elements in the CoPP report : K. Olsson-Francis, P. Doran, V. Ilyin, F. Raulin, P. Rettberg, M-P. Zorzano Meier

It has been focussing on these two findings so far but a more extended report is expected:

Finding 2: The environment on Mars makes the survival, growth, and proliferation of terrestrial organisms on the surface, or suspended in the atmosphere, highly unlikely. However, transport of viable terrestrial organisms to potentially habitable subsurface environments, such as caves, creates a risk of harmful contamination.

Finding 4: Microbial transport and proliferation are highly unlikely in disconnected subsurface environments. Thus, relaxed bioburden requirements could be appropriate for missions that do not access the subsurface, or for missions that access the subsurface (down to 1 m2) where no evidence of ice exists. Exceptions to this finding include buffer zones around subsurface access points and sites of astrobiological interest.

General assessments

The *CoPP report* represents an in-depth contribution to the field of Mars planetary protection, especially:

- Proliferation vs survival, in agreement with COSPAR policy and all past analysis of Special Regions *(e.g. Beaty et al. 2006, Kminek et al. 2010, Rummel et al. 2014)*
- Risk analysis is straight forward
- Focus on biocidal effects of the Martian surface and transport was also outcome from joint COSPAR/NASA workshop series on PP for human missions to Mars (Spry et al. 2021)

We do need to consider "modernizing" planetary protection requirements for Mars exploration (review new literature of observations and experiments, apply new techniques as they become available), especially for future human missions, but ***several areas of knowledge gaps*** identified.

Concerns regarding the following areas

- UV radiation and surface sterilization (in particular lack of consideration of shielding on the surface of Mars)
- Metastable brines and deliquescence on the surface of Mars
- Transport of microorganisms on dust, and shielding/exposure during transport

Ultraviolet UVC solar radiation

We agree that UVC is an effective biocide, **but many caveats and knowledge gaps**:

- The ***CoPP report*** states (page 20) "..***surface microorganisms, or those carried by the wind as aerosols and suspended in the atmosphere, will be inactivated relatively quickly by UVC reaching 20 W/m²***"

20 W/m² is the downwelling UV irradiance on a flat surface facing the sky, at a Mars equatorial region, free from dust cover. Any vertical surface, for instance, will be exposed to the diffuse irradiance which is only about 10-25% of this dose *(Patel et al. 2002)*.

- And UVC is *"**sufficient to inactivate most radiation resistant prokaryotes in a matter of hours to days, depending on the season**."*

This overlooks shielding, spore-forming organisms and other works that have demonstrated viability even after long-time exposure, at the ISS, to radiation *(e.g Kawaguchi et al., 2020).*

TABLE 4. SURVIVAL OF VARIOUS MICROORGANISMS TO SIMULATED MARTIAN UV SPECTRUM AND INTENSITY[a]

	"Mars" LD_{90}				
	Unshielded (kJ/m^2)	*Shielded (kJ/m^2)*			
Organism	*Time on Mars*[b]	*Time on Mars*	*Shielding material*	*Thickness*	*Reference*
Bacillus subtilis spores, monolayers	0.35 kJ/m^2 7 s	64 kJ/m^2 21 min	Neutral density filter *tau* = 3.5 (global dust storm)	—	Schuerger *et al.*, 2003
		Essentially 100% survival "forever"	Pelagonite dust	0.5 mm	
Chroococcidiopsis sp., monolayers	10 kJ/m^2 3 min, 20 s	Essentially 100% survival "forever"	Mars soil simulant or gneiss	1 mm	Cockell *et al.*, 2005
B. pumilus SAFR-032 spores, in water	16 kJ/m^2 5 min, 20 s	n.t.[c]	—	—	Newcombe *et al.*, 2005
B. subtilis spores, multilayers	12 kJ/m^2 4 min	n.t.	—	—	Tauscher *et al.*, 2006
Deinococcus radiodurans	28 kJ/m^2 9 min, 20 s	n.t.	—	—	Pogoda de la Vega *et al.*, 2005
D. radiodurans	no survival at 145 kJ/m^2 48 min, 20 s	No survival at 145 kJ/m^2 48 min, 20 s	Nanophase hematite	8–10 nm	Pogoda de la Vega *et al.*, 2007
		97.5% survival at 145 kJ/m^2 48 min, 20 s	Goldenrod hematite	300 nm	
Psychrobacter cryohalolentis	30 kJ/m^2 10 min	720 kJ/m^2 1 h, 20 min	Mars simulation (-) UV	—	D.J. Smith *et al.*, 2009
Halococcus dombrowskii	0.0–0.9 kJ/m^2 0–18 s	30 kJ/m^2 3 min	Halite	5 mm	Fendrihan *et al.*, 2009
Natronorubrum sp. strain HG-1	8 kJ/m^2 2 min, 40 s	Cells did not survive drying	Atacama soil	—	Peeters *et al.*, 2010

[a]Experiments were performed in various Mars simulation chambers (600–850 Pa, either 100% CO_2 or Mars gas mixture, temperatures ranging from −35°C to ambient).
[b]Conversion factor: total UV (200–400 nm) dose on clear-sky, noonday Mars is ~0.05 kJ/m^2 s. So, for example, a dose of 10 kJ/m^2 corresponds to 200 s, or 3 min 20 s.
[c]n.t. = not tested.

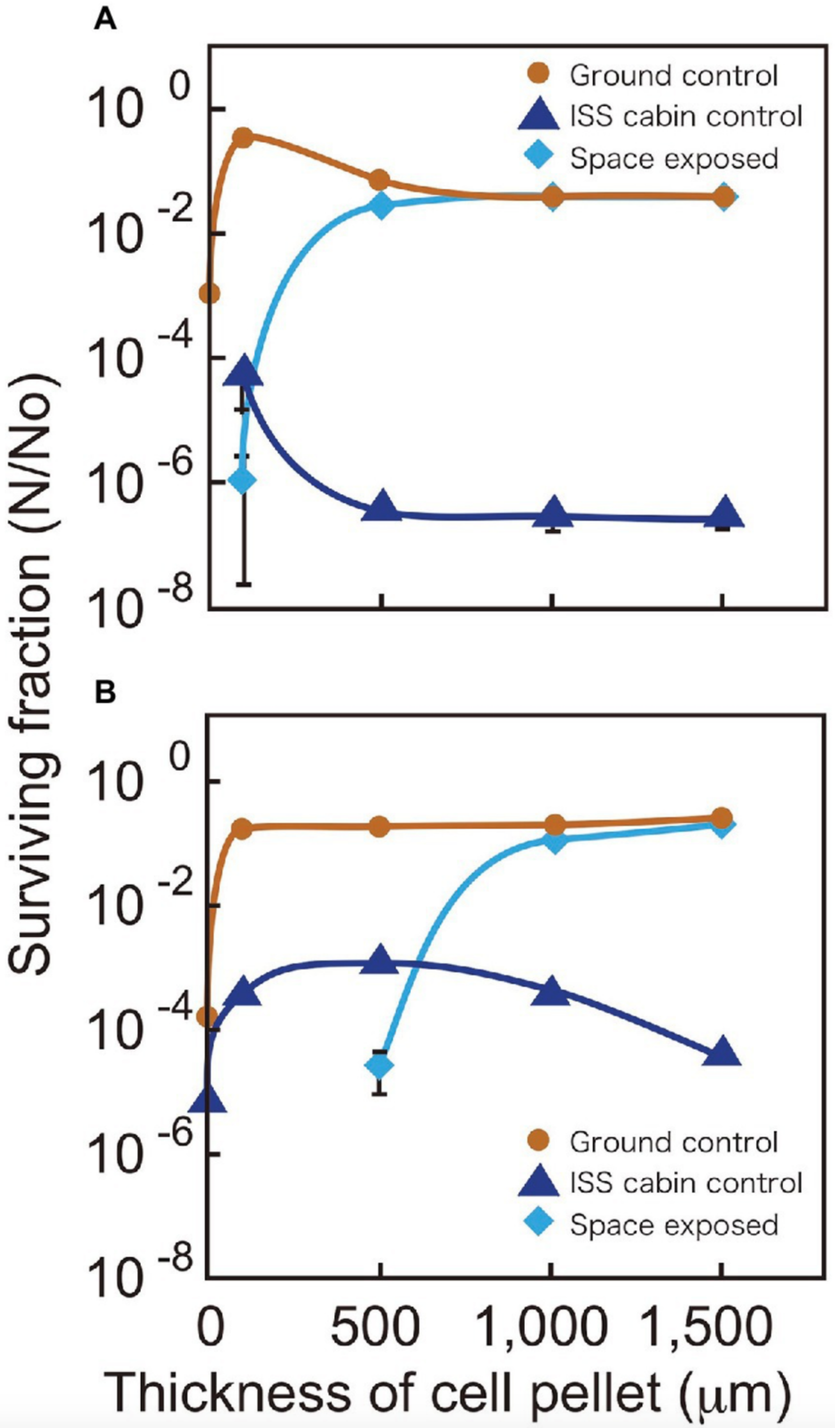
From Rummel et al. 2014

Shielding

Dried *Deinococcus radiodurans* strains exposed to LEO conditions on the ISS

- 500 µm thickness were alive after 3 years of space exposure
- Repaired DNA damage at cultivation
- Survival time predicted to survive in space conditions : 2-8 years

Kawaguchi et al., 2020

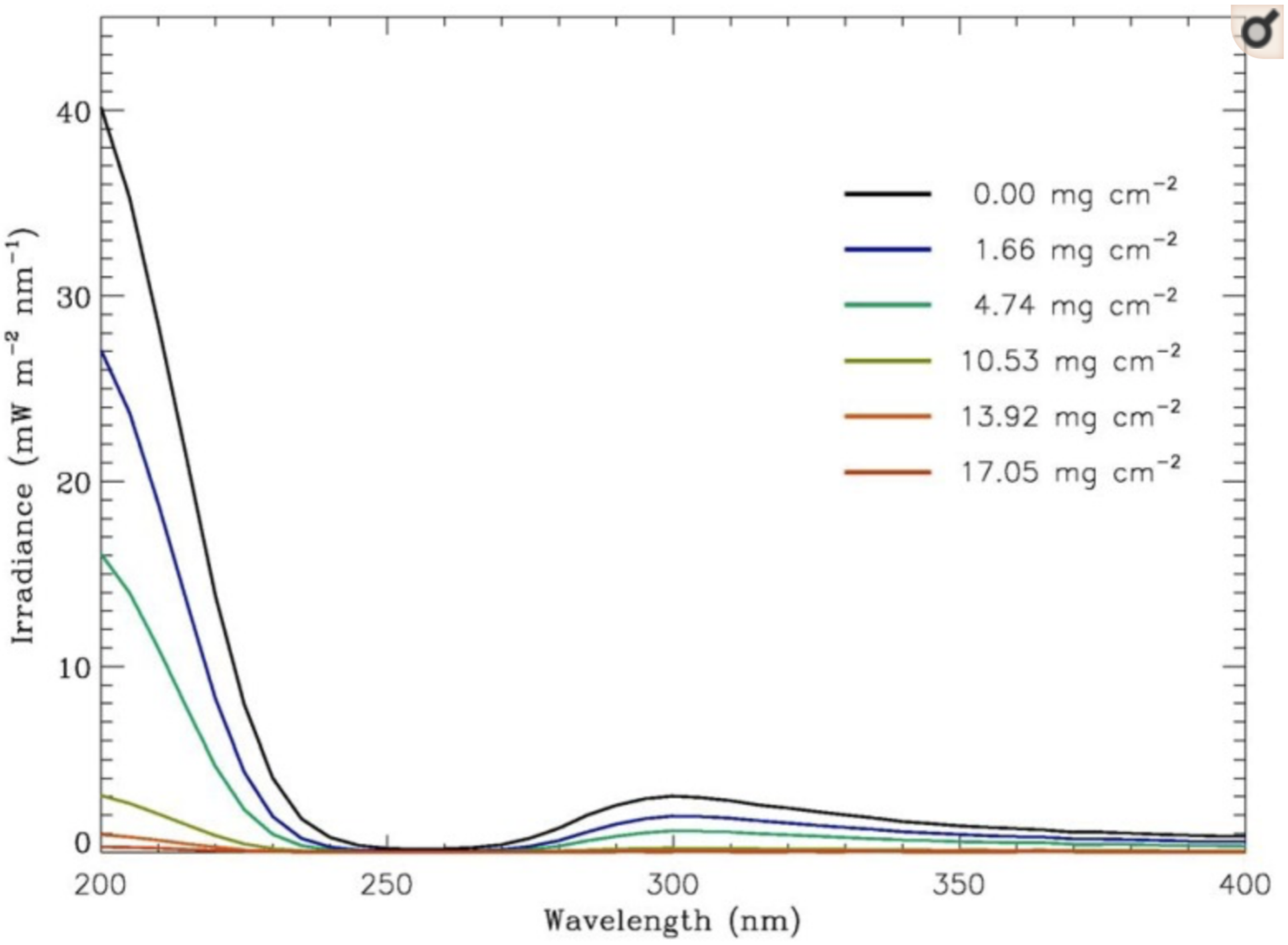


Dust shielding

~1.1 μm thickness reduces the transmittance from 100 to 97%

~300 μm drops to basically 0

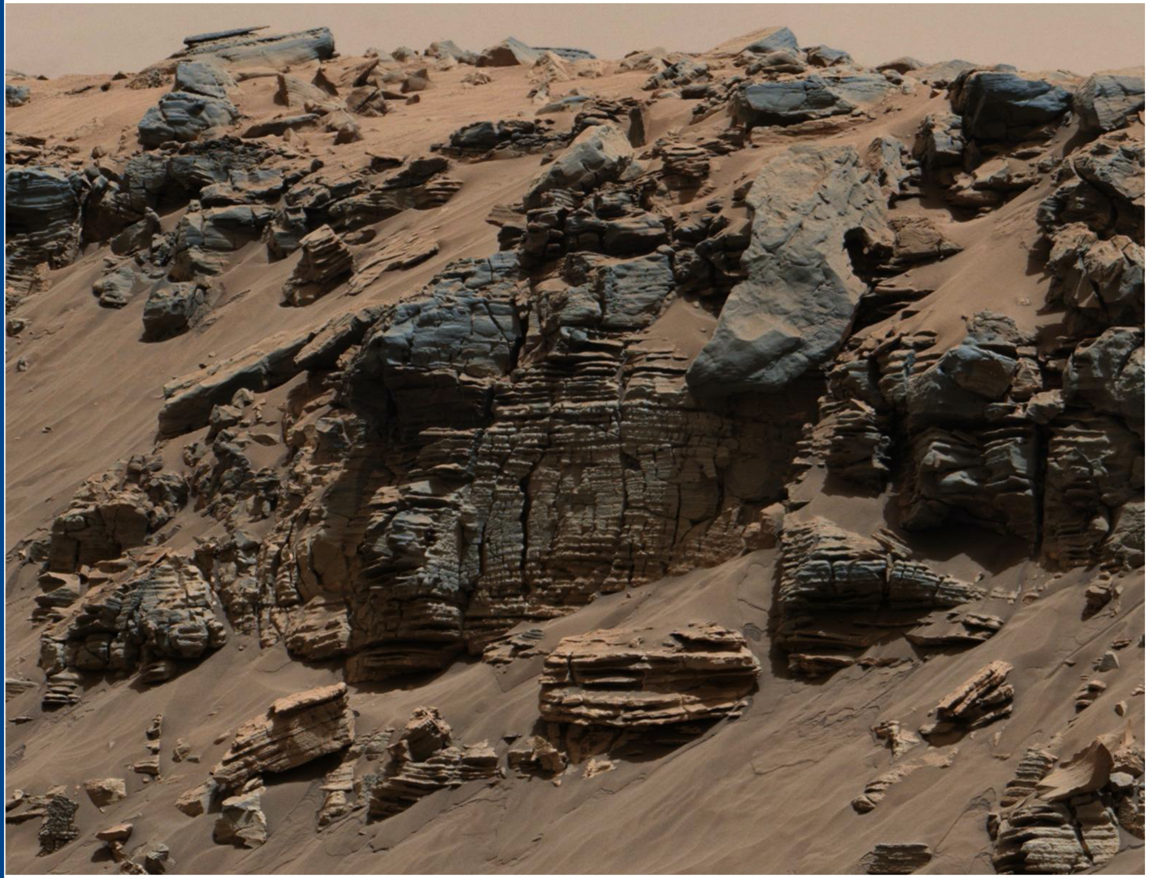
Dust would be able to protect the microorganisms



tance spectra of deuterium lamp measured underneath sample for different basalt dust depositions with increasing mass.

Muñoz Caro, 2006

Distribution of caves



Holey ground on Mars. Image from Curiosity, sol 712

***CoPP Report:* "Until high-resolution images of the Mars surface are acquired that allow for the identification of cave openings as small as ~1 m, caution must be exercised."**

- 1 m seems to be driven by our limitations to resolve things from space - irrelevant to microbes
- Even cave openings > 1 m will not all be lying on a horizontal surface visible from space
- Mars is a geologically complex planet, there are many places to hide. This image for instance shows many cavities that could lead to deeper cavities with the characteristics of a cave discussed in the CoPP report (e.g. 1 to 2 m ceiling)

Caves from fractured rocks on Mars

Surface "cave" at Jezero Crater, a few meters away from the sampling site of Perseverance

Image from Perseverance, sol 265

Brines and Deliquescence on the surface of Mars

CoPP report: ***"The committee concludes that temperature and water activity conditions that allow subsurface microbial growth … are possible for portions of the upper few tens of cm of the Martian subsurface in closed-systems".***

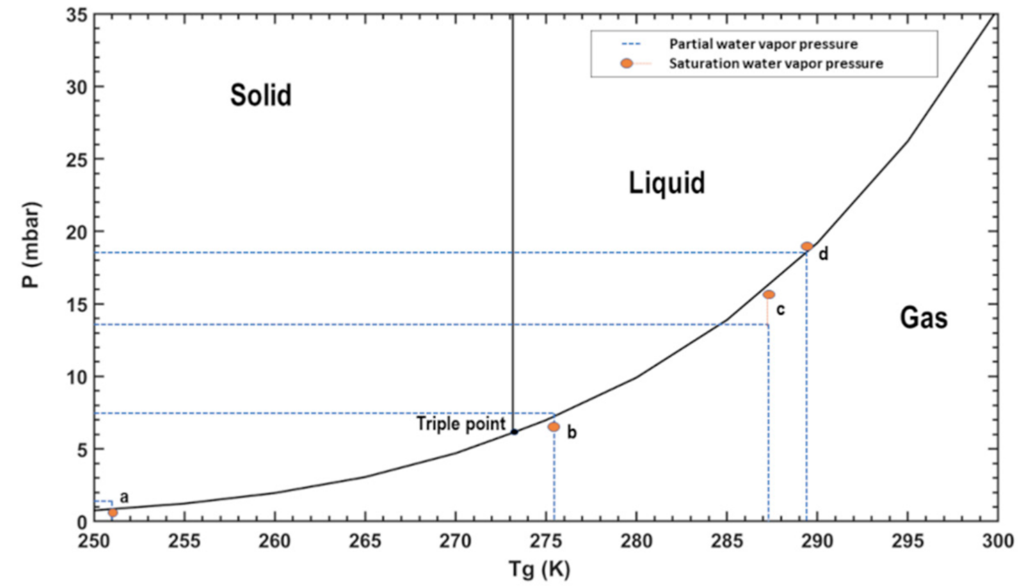
Recent literature suggests that this is also feasible for <u>open-systems</u>:

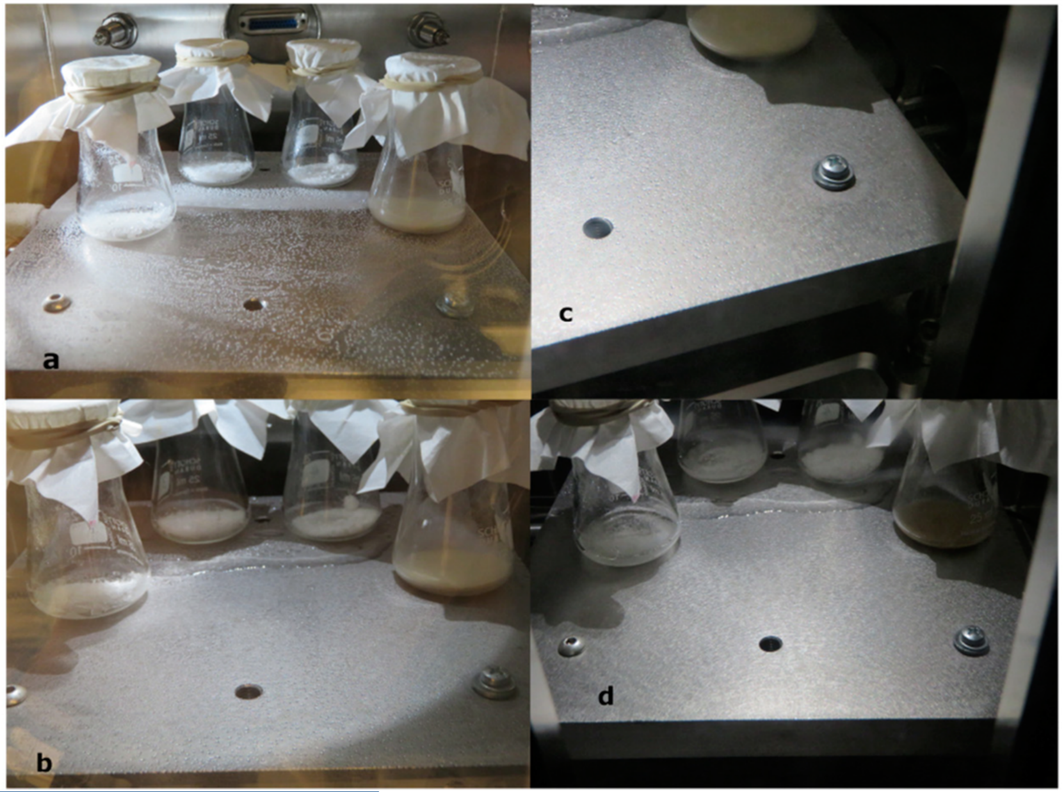
"Considering that there is no exposure to winds or direct sunlight in our experimental facility, our simulations may represent liquid evaporation conditions in sheltered areas, such as caves, under rocks, or in small-sized regions artificially created within parts of spacecrafts in contact with the ground and atmosphere." *(Vakkada Ramachandran et al. 2021).*

***CoPP report:* "Deliquescence could potentially occur in the shallow subsurface (i.e. top most 10 cm), but there is still limited knowledge about the kinetics"**

There are recent experiments that show how (long-lived) brines and also (short-lived) pure liquid water can be formed *(Vakkada Ramachandran et al. 2021)* :

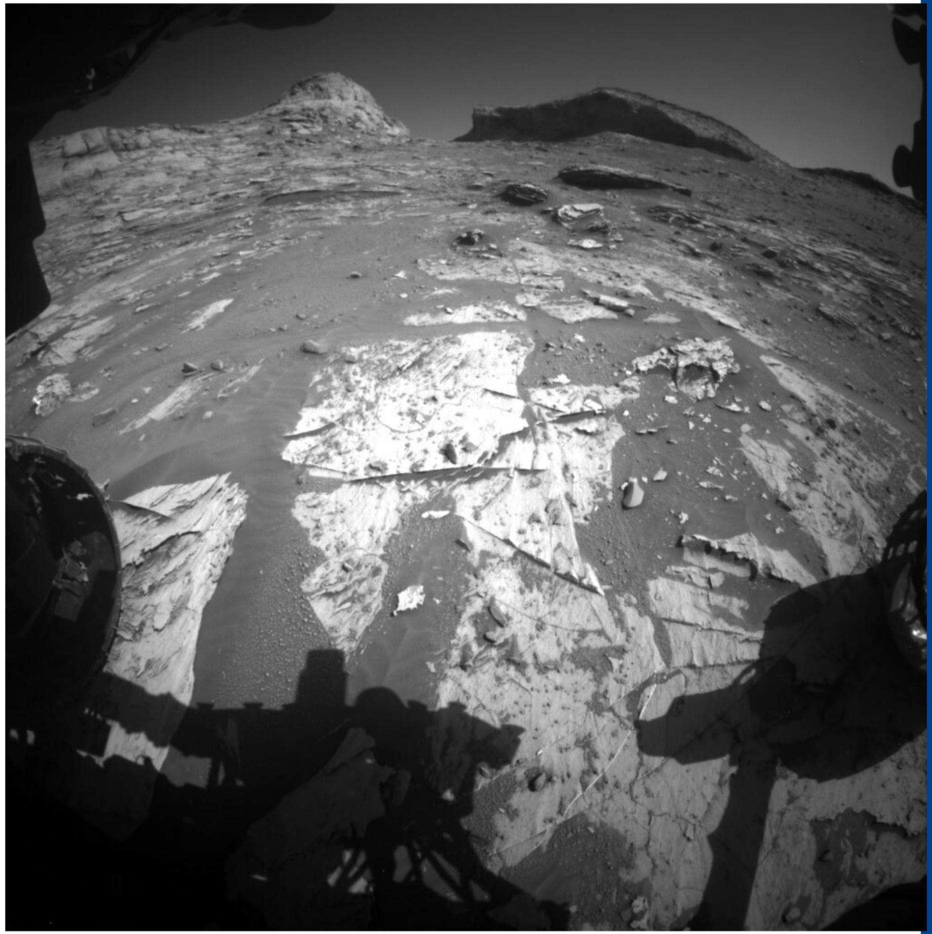
- Frost forming spontaneously on a surface with saturation and when the temperature, this frost can transform into liquid water (above 0°C) and persist for up to 3.5 to 4.5 h at Martian surface conditions





Assumption relating to the distribution of salts

- Known abundances of deliquescent salts, from Phoenix and MSL measurements, constitute only ~0.5 wt % of the Martian regolith or less, suggesting that such brines would be dispersed and forming at the grain scale.
- Landed rovers have seen highly concentrated regions of salts e.g. sulfates *(Rapin et al., 2016)*
- Liquid water can exist transiently, for a few hours, on the source, both supported by salts (that form brines) and spontaneously when saturation is reached.
- Many microorganisms on Earth can proliferate with a few hours and some can live upon absorbed water in the salts when relative humidity rises *(Davila et al., 2013)*.



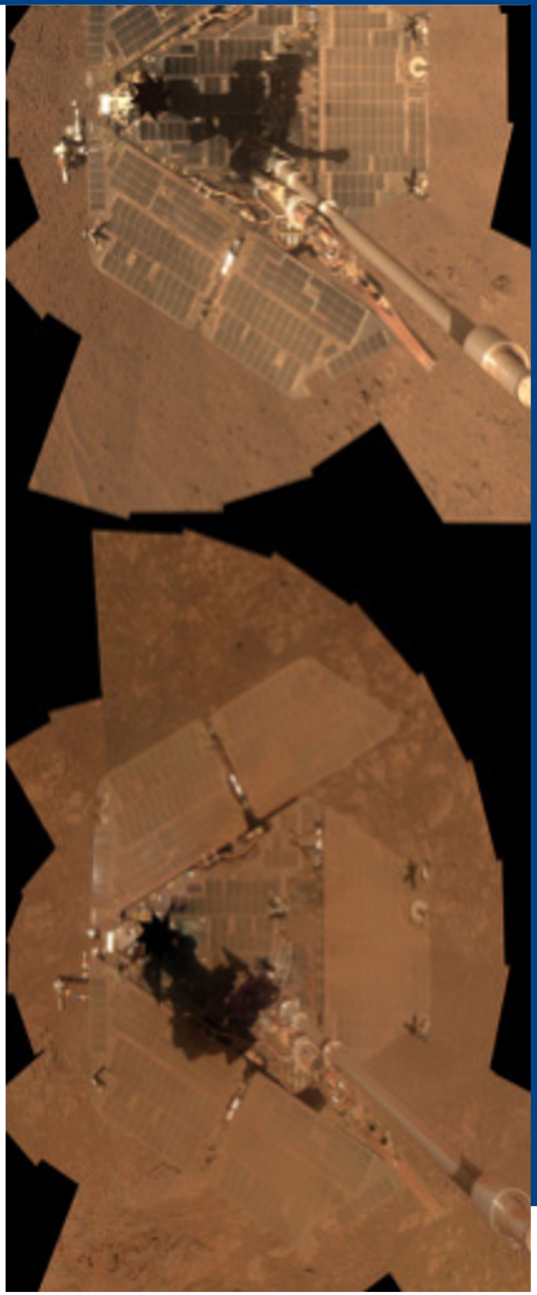
Clay-sulfate transition, Sols 3287-3288: Assessing a New Potential Drill Target MSL

Transport and atmospheric circulation

CoPP Report: ***"The Martian atmosphere is not sufficiently dense to attenuate solar UVC radiation or provide protection to suspended Earth organisms."***

But life can be transported from the spacecraft through the air, protected in grains of dust, and still be shielded from UV within a pack of dust and/or by the total column of dust, which specially during dust storms absorbs UV very efficiently

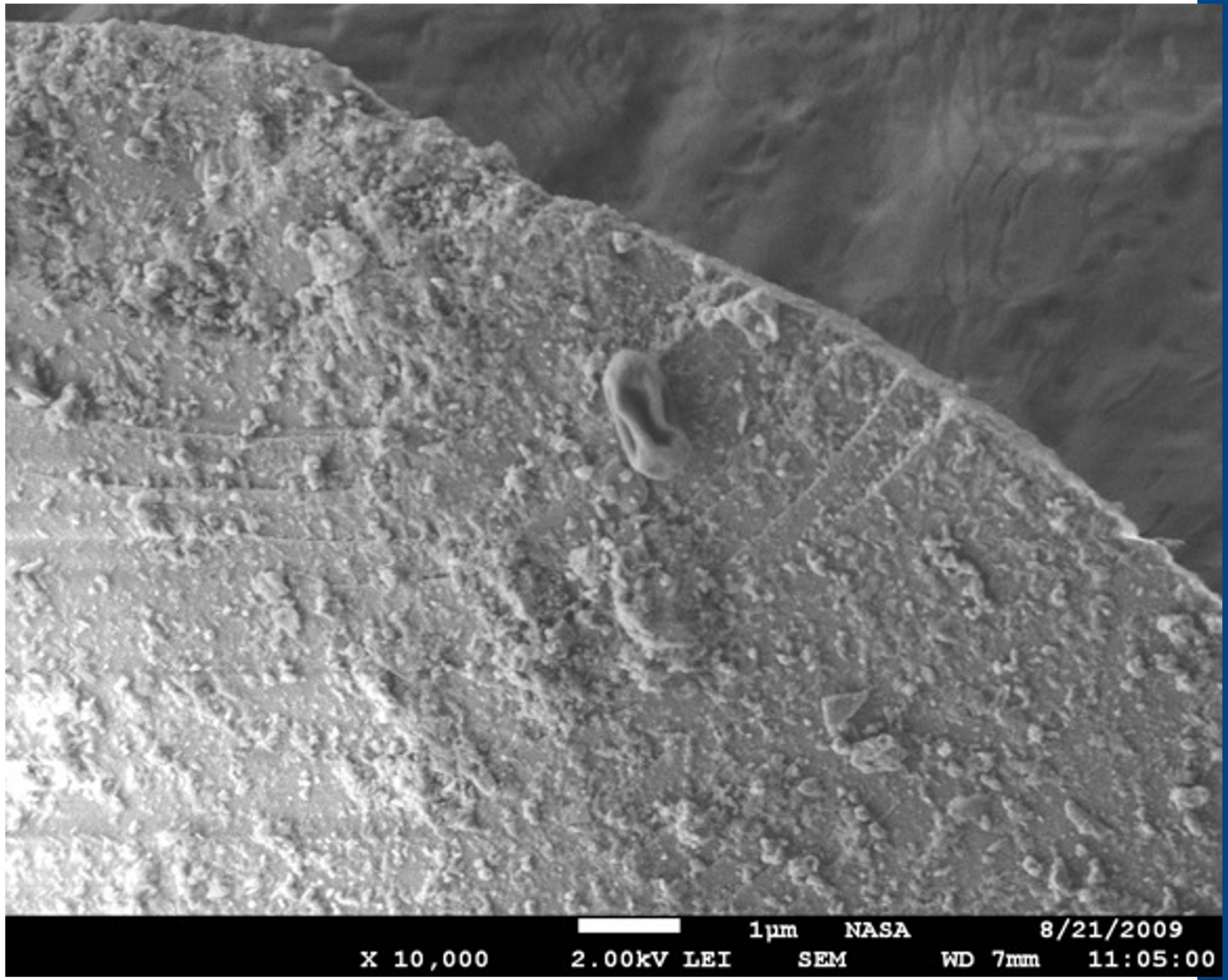
- During a dust storm in Gale Crater, atmospheric opacity increased from 1 to 8.5, and *"the daily maximum UV radiation decreased by 90%" (Viúdez-Moreiras et al, 2019).*
- MER measurements have revealed that after 30 sols there is a layer on top of every flat, exposed surface that absorbs 12% of the incident UV radiation *(Kinch et al., 2015).*
- The Mars Pathfinder team used indirect measurements and estimated dust deposition rates of about 20–45 µm per Earth year *(Jeffrey et al., 2003)*.



NASA's Mars Exploration Rover Opportunity taken in late March 2014 (top) showing that much of the dust on the rover's solar arrays has been removed by winds since a similar portrait from January 2014 (bottom)

Potential atmospheric transfer of microorganisms

- Aerobiological dispersal has been demonstrated to exist in Mars analogue environments *(Azua-Bustos et al., 2019; Smith et al 2012)*.
- On Mars the airborne transport of micron-sized mineral grains (dust) is common.
- During a global storm, the characteristic size of aerosols in suspension can reach 8 µm (Lemmon et al., 2019).
- A layer of 8-µm of mineral dust can screen only 20% of the incident UV radiation, but the opacity of the atmosphere during a dust storm is so high that the UV dose is reduced by a factor of 10 at least *(Viúdez-Moreiras et al., 2018)*.



SEM: bacterial spore atop a grain of dust that journeyed from Asia high in the troposphere to the West Coast. Image Credit: NASA Kennedy Space Center

Preliminary conclusions (1)

- PPP is thankful for the CoPP report(s) and other recent activities that bring attention to the need for possible adaptation of Planetary Protection measures applied to future Mars exploration. This is an important and timely element for consideration.

- **We agree with the CoPP report's findings *(Summary)*, i.e. "*planetary protection protocols aimed at avoiding contamination remain necessary to prevent compromising future investigations of extraterrestrial life. In addition, despite the increase in scientific information about Mars, much about its surface and subsurface remains underexplored, creating the need for caution in avoiding contamination harmful to future scientific investigations of extinct or extant life on Mars.»***

- PPP and CoPP findings thus agree on the need for increasingly urgent new information on several items pertaining to the survival, growth and proliferation of living organisms on Mars.

Preliminary conclusions (2)

Preliminary results of the **PPP subcommittee of experts** assigned with the task to review the CoPP report in view of future adjustments to the COSPAR PP Policy for Mars put forward the following initial comments on parts of the report's findings.

- The report relies heavily on UVC on the surface of Mars being biocidal. However, the many ways ***microbes could be shielded*** within µm to mm of the surface or could survive and be transported elsewhere is not sufficiently addressed in the current report.
- According to the current and recent literature, ***viable cells and spores can be transported*** through the atmosphere, protected by grains of dust (within a pack and/or by the total column of dust) from the UV. Much more information (in situ data) on atmospheric circulation is needed to allow for any firm conclusions about sterilization of microbes during transport. Current models are *largely* unsupported by data.
- ***Water can be formed*** at small scales and be transiently stable on the surface of Mars: **a)** wherever there are salts, by interaction of salts with atmospheric water to form brines and **b)** wherever there is saturation, by formation of frost and its transient evaporation as dew. Many microorganisms on Earth can proliferate with a few hours of dew and some can live upon ***water absorbed in the salts*** when relative humidity rises.

Preliminary conclusions (3)

- In view of the above, the PPP subcommittee contends that there is **neither sufficient new evidence in the literature nor community consensus** to conclude that "*survival, growth, and proliferation of terrestrial organisms on the surface, or suspended in the atmosphere is highly unlikely (Finding 1)*".
- It is possible that there are **many places to hide** on the geologically complex Martian surface, beyond just caves with openings visible from space.
- Furthermore, current knowledge indicates that **ice in the near surface is not necessarily a precursor to habitable zones** (*part of Finding 4*).

In order to respond to the urgent need for data : in situ high-resolution meteorological data at the regional and global scale from Mars and ground-based testing (doesn't come for free…). Both aspects are not available yet, none of the current missions provide that.

As a first step, input from the community so as to identify needs and lead to a better understanding of such aspects of Martian exploration and to accordingly adapt the current Policy for Planetary Protection, the PPP invites collaboration with CoPP to promote, organize and sponsor studies, workshops and other activities as necessary.

At the COSPAR GA 2022 in Athens (July 16-24) ??!!

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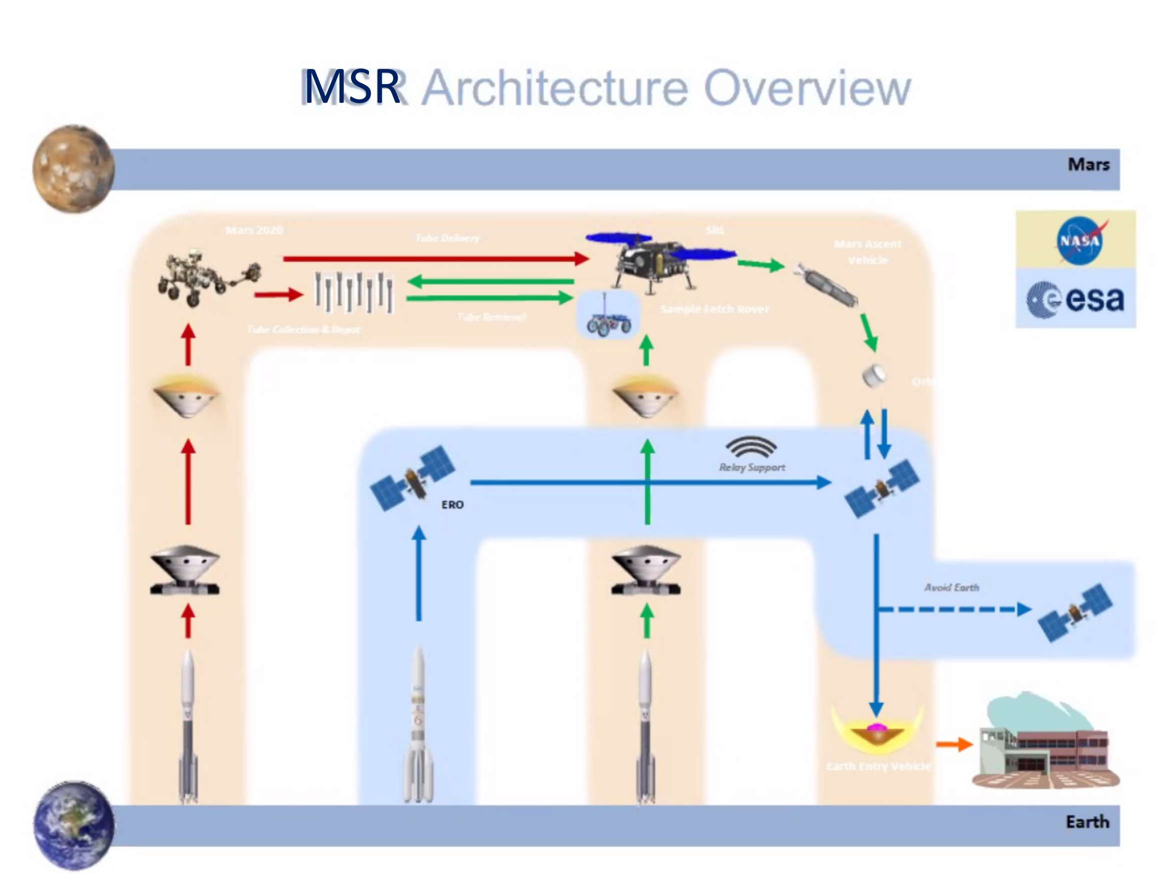
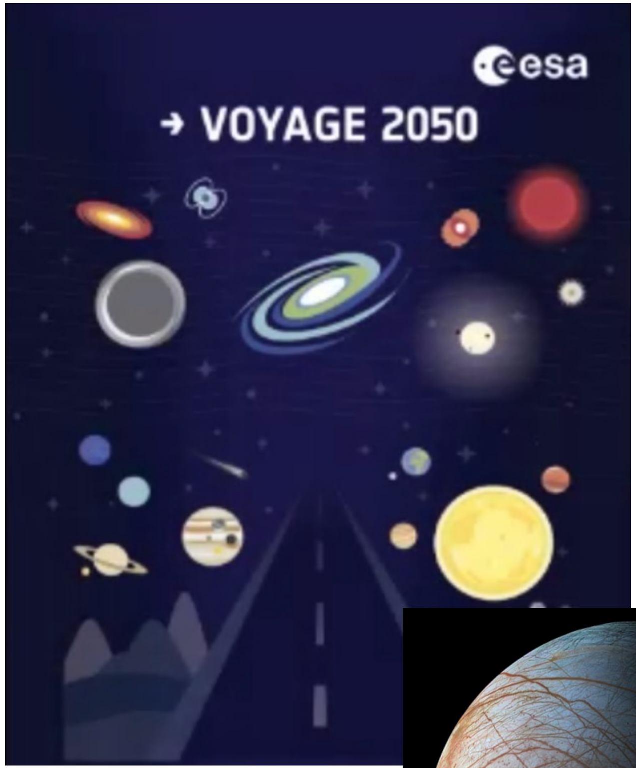
FUTURE ITEMS

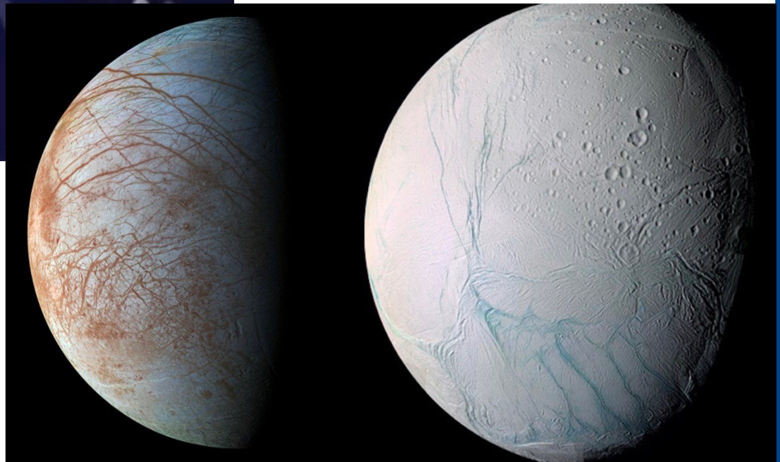
Martian exploration

Further exploration of moons of the giant planets





Moons of the giant planets :
1 of the 3 Voyage 2050 Themes



Are we ready for the next step?

COSPAR/NASA/ESA workshop series to refine planetary protection requirements for human missions to Mars (2016, 2018 and 2019 at LPI and 2020 virtual) identified two (out of four) high priority knowledge gaps that would also apply to robotic missions:

- Natural transport of (terrestrial biological) contamination on Mars.
- Synergistic biocidal effects of the martian environment on the survival and growth of spacecraft (robotic and human) associated microbiome.

An **informed partitioning of the martian surface** and the establishment of quantitative planetary protection requirements (reflecting this partitoning) are only possible based on an increased understanding of the natural transport of biological contamination and their fate on Mars. This requires new targeted measurements on Mars and ground-based research.

"The current state of research is not yet adequate to determine whether there are regions on Mars where human explorers or commercial missions might land with minimal planetary protection implications", NRC-SSB, 2020

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

Planetary protection categories and requirements are not cast in stone and evolve over time as new information becomes available, i.e. The Policy has been updated twice in 2020 and 2021.

- COPUOS in its 2017 report noted the long-standing role of COSPAR in maintaining the Planetary Protection Policy as a reference standard for spacefaring nations and in guiding compliance with Article IX of the Outer Space Treaty

- 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

- *Planetary protection technologies are for cleaning and sterilizing spacecraft and handling soil, rock and atmospheric samples. Precautions are taken against introducing microbes from Earth.*
- *At the same time, when the samples are returned to Earth, there is need to avoid backward contamination and preserve our biosphere Hot topic: sample receiving facilities*

PPP Publications

+ Numerous presentations by PPP members in international meetings
***+** inputs to the press in many countries*

- Coustenis, A., Kminek, G., Hedman, N., 06/**2019**. The challenge of planetary protection. *ROOM Journal #2(20)*
- Coustenis, A., Kminek, G., Hedman, N., The COSPAR Panel on Planetary Protection., **2019**. The COSPAR Panel on Planetary Protection role, structure and activities. *Space Res. Today* 205, DOI:10.1016/j.srt.2019.06.013.
- Raulin, F., Coustenis, A., Kminek, G., Hedman, N., **2019**. Preface to the special issue "Planetary protection: New aspects of policy and requirements". *Life Sci. Space Res.* 23, 1-2. *See also the whole issue open access.*
- Fisk, L., Worms, J-C., Coustenis, A., Hedman, N., Kminek, G., **2020**. Introduction to the new COSPAR Policy on Planetary Protection. *Space Res. Today* 208, August 2020.
- The COSPAR Panel on Planetary Protection, **2020**. « COSPAR Policy on Planetary Protection ». *Space Res. Today* 208, August 2020, Pages 10-22. DOI: 10.1016/j.srt.2020.07.009.
- The COSPAR Panel on Planetary Protection, **2020**. « Planetary Protection Policy: For sustainable space exploration and to safeguard our biosphere ». *Research Outreach* 118, 126-129. DOI: 10.32907/RO-118-126129.
- Coustenis, A., Hedman, N., Kminek, G., The COSPAR Panel on Planetary Protection, **2021**. "The COSPAR Panel on Planetary Protection: Recent Activities". *Lunar and Planetary Science Conference no 52,* 15-19 March.
- Coustenis, A., Hedman, N., Kminek, G., & COSPAR Panel on Planetary Protection, **2021**. "The COSPAR Panel on Planetary Protection: Recent Activities". *Global Space Exploration (GLEX),* 14-18 June, St Petersbourg, Russia.
- 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
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https://cosparhq.cnes.fr/scientific-structure/panels/panel-on-planetary-protection-ppp/

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

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

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

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.

Category V: Two subcategories exist - unrestricted Earth return for solar system bodies deemed by scientific opinion to have no indigenous life forms, and restricted Earth 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

<u>Category I:</u> Flyby, Orbiter, Lander: Undifferentiated, metamorphosed asteroids; others TBD

<u>Category II:</u> Flyby, Orbiter, Lander: Venus; **Moon** ~~(with organic inventory)~~; 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

<u>Category III:</u> Flyby, Orbiters: Mars; Europa; Enceladus; others TBD

<u>Category IV:</u> Lander Missions: Mars; Europa; Enceladus; others TBD

<u>Category V:</u> Any Earth-return mission.
"Restricted Earth return": Mars; Europa; Enceladus; others TBD
"Unrestricted Earth return": Venus, Moon; others TBD

†Additional analysis is required.

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