

# My Opinion / Recollections Regarding The Perspective of the Planetary Protection Independent Review Board (PPIRB)

Christopher H. House

# Outline

- PPIRB Background
- Origins of Planetary protection (PP) policies
- Interplay between PP policy, implementation, and exploration
- New discoveries with respect to bioload replication at Martian surface
  - Gullies and Recurring Slope Lineae
  - Deliquescence
- Other considerations
  - Induced special regions
  - Martian meteorites
  - Nature of microbial colonization
  - Nature of spacecraft bioload and relevant PP microorganisms
  - New modern and/or flexible approaches
- Summary and Questions



# PPIRB Background

- Chartered: By NASA/SMD AA Zurbuchen.
- Charter Summary: “An assessment to include analysis of the scientific, engineering, industrial, legal, and program management aspects of planetary protection (PP). Results of the assessment will be documented in a non-consensus final report presentation.”
- Term: July-September 2019
- Membership: 12 planetary scientists, biologists, private & civil sector space reps.
- Meetings/Telecons: 4 in person multi-day meetings; 11 working telecons.
- Report: Reviewed within NASA prior to delivery. Released 18 Oct 2019.
- Briefed: SMD, NASA Administrator, EOP Staff, NAC, SSB, House Science Committee Staff, NAC Science Committee. JAXA, ESA, COSPAR, NAS



# PPIRB Background

## PPIRB Membership

Dr. Alan Stern, PPIRB Chair

Dr. Edward (Beau) Bierhaus

Dr. Wendy Calvin

Dr. Amanda Hendrix

Dr. Christopher H. House

Dr. Hernan Lorenzi

Mr. Tommy Sanford

Dr. Erika Wagner

Dr. Andrew Westphal

Mr. Charles Whetsel

Mr. Paul Wooster

Dr. T. Jens Feeley, Study Manager

Southwest Research Institute

Lockheed Martin

University of Nevada-Reno

Planetary Science Institute

Pennsylvania State University

J. Craig Venter Institute

Commercial Spaceflight Federation

Blue Origin

University of California at Berkeley

Jet Propulsion Laboratory

SpaceX

NASA Headquarters (Ex Officio)



# PPIRB Report Overview

## Approximately 80 PP Findings and Recommendations, Including:

- Clarifying and Streamlining Processes within NASA
- Advancing Protocols with More Modern Technology
- Reducing Burdens on Missions
- Advancing Policies for Private Sector Missions

## Sample Topics in the PPIRB Report:

- Planetary Protection Categorization
- Human Spaceflight
- Private Sector Initiatives and Missions
- Robotic Mars Sample Return
- Ocean Worlds Exploration



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### **Most important findings and recommendations:**

- PPIRB all agreed PP is important
  - Should enable exploration
  - NASA leads by example for all varieties of missions
- Establishment of a permanent board for PP (that's you)



# Selected Findings & Recs: Mars (Robotic)

Supporting Recommendation: For space activities without significant NASA involvement (including private sector robotic and human planetary missions), NASA should work with the Administration, the Congress, and private sector space stakeholders to identify the appropriate US Government agency to implement a PP regulatory framework.

Supporting Recommendation: The PPO should exploit new discoveries and new technologies to better categorize exploration targets, create better forward and backward PP implementation protocols, and lower PP cost and schedule impacts on projects.

Major Recommendation: NASA should reconsider how much of the Martian surface and subsurface could be Category II vs. IV.

Category II missions comprise all types of missions to those target bodies where there is **significant interest** relative to the process of chemical evolution and the origin of life, but where there is only a **remote chance that contamination** carried by a spacecraft could compromise future investigations.

Major Recommendation: Planning for a Mars Sample Receiving Facility (MSRF) should be accelerated, and should be kept as pragmatic as possible so as not to unduly drive the cost or schedule of MSR.

# Origins of PP policies

## • 1964 COSPAR RESOLUTION

- Establishes “interim” Planetary Protection probability goals for Mars
- Notes that the Lunar surface is different than Mars because the conditions preclude microbial replication
- Concept of a period of astrobiological exploration, followed by human exploration...
- Context: Pre-Viking notion of a habitable Martian soil

### Resolution 22 Bibliographies of Space Science Papers

COSPAR welcomes the fact that an increasing number of national reports have an appendix containing a bibliography of papers and reports relating to space science, but calls upon scientists to the fact that such bibliographies are valuable to scientists and, in accord with Section 3.2 of the Guide, should be included in all national reports.

### Resolution 23 International Multilingual Glossary of Space Science

COSPAR believing that the need for international multilingual glossaries of space science terminology (including vehicle terminology) requires further study, considers a temporary panel under Working Group 5 for this purpose consisting of Dr. M. Koschik and Dr. J. W. King (secretary), Prof. M. Nierlich, Dr. J. Borch and Dr. P. H. A. Swarth, and Indian National Committee and the Russian Union to cooperate with the Panel in an attempt to determine the need for a multilingual glossary.

### Resolution 24 Simultaneous Rocket Experiments using Different Techniques

COSPAR recognizing the fact that very accurate knowledge of the atmospheric parameters in the height range from 80–200 km is necessary in order to improve our physical understanding of the upper atmosphere, recommends rocket experiments using different techniques for simultaneous observations. Of particular importance is the simultaneous investigation of the chemical composition by mass spectrometry and by radiation absorption techniques.

### Resolution 25 See page 17

#### IX. — The Consultative Group on Potentially Harmful Effects of Space Experiments

The Consultative Group submitted its first report, with various appendices, dealing with:

- Pollution of the Upper Atmosphere
- Orbiting Debris
- Contamination of the Moon and Planets

An interim summary of these reports is given by the COSPAR Resolution No. 26, quoted below, which was adopted by the Plenary Meeting.

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### Resolution 26 COSPAR Position with regard to the Plenary Report of its Consultative Group on Potentially Harmful Effects of Space Experiments

COSPAR notes with appreciation and interest the extensive work done by the Consultative Group on Potentially Harmful Effects of Space Experiments as expressed by the Group in its report and annexes.

#### COSPAR:

1. instructs its Secretariat to make this Report and annexes available to ICSU, the following bodies of COSPAR, and other interested parties;

2. welcomes the encouraging conclusions of the Consultative Group that harmful contamination of the upper atmosphere on a long term global basis is unlikely on present and expected scale of flights of super rockets and the virtues of experimental testing. COSPAR urges its adhering organizations to report any major new experiment which may produce harmful contamination. Moreover, it urges them to encourage these scientists to continue studies of the following matters:

- evaluation of exchange flows between the various regions of the upper atmosphere, especially between 60 and 100 km;
- short and long term local and aural effects of rocket contamination in the upper atmosphere;
- the possibility of any catalytic effects which might trigger chemical and photochemical processes in the upper atmosphere; and
- radiation balance in the upper atmosphere and its dependence on changes in composition there;

3. welcomes the conclusion of the Consultative Group that no interference to optical and/or radio astronomy has resulted from the tests of orbiting debris launched in May 1963, and recommends to its Members that any proposals for future experiments of this sort also be given the benefit of thorough evaluation by the scientific community and notably by the International Astronomical Union, in order to check in advance their harmfulness to other scientific research;

4. affirms that the search for extraterrestrial life is an important objective of space research, that the planet Mars may offer the only feasible opportunity to conduct this search during the foreseeable future, that contamination of this planet would make such a search for more difficult and possibly even prevent

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for all time an unimpeded search, that all practical steps should be taken to ensure that Mars be not biologically contaminated until such time as this search can have been satisfactorily carried out, and that cooperation in proper scheduling of experiments and in use of adequate spacecraft sterilization techniques is required on the part of all deep space probe launching authorities to avoid such contamination;

5. accepts, as tentatively recommended in other documents, a sterilization level such that the probability of a single viable organism aboard any spacecraft intended for planetary landing or atmospheric penetration would be less than  $1 \times 10^{-6}$ , and a probability limit for accidental planetary impact by unsterilized fly-by or orbiting spacecraft of  $2 \times 10^{-4}$  or less;

6. calls attention to the opinion of its Consultative Group that although less rigorous sterilization techniques are required for lunar landings, because the lunar surface conditions would almost certainly exclude microbial replication, it is desirable that skills designed for deep inner solar system biology should be very carefully applied to avoid contamination of regions below the surface where a more favorable environment might exist;

7. calls on its members that are concerned with planetary probes to urge the vehicle construction and launching authorities in their countries to try to achieve these sterilization objectives and especially to forego the launching of planetary atmospheric entry and orbiting vehicles until such time as the above-mentioned level of sterility can be achieved with a high degree of certainty;

8. requests its members concerned with planetary probes to report to COSPAR any disagreement or objection they may have to the use of these tentative objectives or to any other aspects of Annex IV of the Consultative Group Report, and expresses the hope that the Consultative Group will arrange concerted studies in the area of biological contamination of the moon and planets, taking into account any such reports or comments as may be received; and finally,

9. authorizes the Consultative Group in consultation with the Chairman of Working Group 5 to arrange for the convening of an international conference on biological sterilization and sterility testing techniques at any time and appropriate, provided it can be carried in advance of substantial participation in the conference by scientists of both the major deep space probe launching authorities.

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#### IX. — Future COSPAR Meeting and Symposium

COSPAR accepted unanimously the invitation to hold the Eighth COSPAR Meeting and Ninth International Symposium of Space Science at Buenos Aires, during May 1965.

The tentative program of this Symposium appears to be made up of the following parts:

1. Galactic and extragalactic astronomy. This subject would form the specialized part\* of the Symposium in the field of physical sciences and the corresponding Program Committee would consist of Prof. H. C. van de Hulst, Dr. H. Friedman, a Soviet Scientist, a Latin American Scientist and the President of IAU Commission 44 on Astronomical Observations from outside the Terrestrial Atmosphere, ex officio.

2. Problems of the Atmospheric Circulation. One day would be probably devoted to this special subject with emphasis on topics of special interest to the Southern Hemisphere.

3. Latest Results in Space Research. This usual part of the COSPAR Symposium would be covered for contributed papers which would be selected very strictly. It was suggested that instead of detailed papers presenting data on individual experiments, summaries of several different related experiments should be encouraged. It was also suggested that papers on results of IQSV experiments be stressed in these sessions.

4. Space Researcher's divided into:

- Human Physiology
- Orbital Effects in Biology
- Ecology, Microclimate analysis, Techniques of Telemetry.

The sessions in part (c) will not be parallel since the participation of physicists and astronomers in this part is especially wanted.

5. Panel discussion on Optimization of Instrumentation of Space Experiments from the Standpoint of Data Processing.

Please note that a first circular will be edited in the nearest future by the COSPAR Secretariat giving more details on the above program, taking account of the decisions of the next meeting of COSPAR Bureau.

\* (1 or 1½ day)

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COSPAR. COSPAR RESOLUTION 26.5, COSPAR Information Bulletin 20, 25-26, 1964.

## • Article IX of the 1967 UN Outer Space Treaty (a.k.a, the non-interference provision)

- Establishes doctrine of peaceful, cooperative exploration of space
- Not intended to hinder exploration

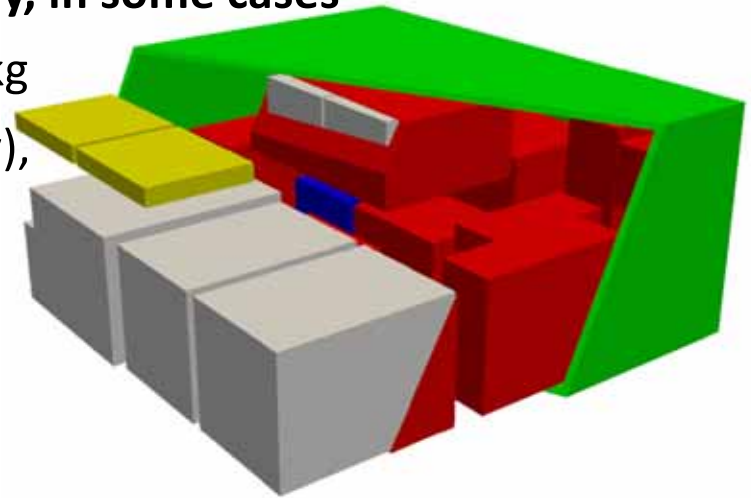


# Accepted PP parameters

- **Forward Contamination** – The delivery of terrestrial biology from Earth to other celestial bodies, and specifically, as it relates to adversely affecting the future investigations.
- **Backward Contamination** – Harmful contact between terrestrial biology and pathogens or biology arriving on Earth from other celestial bodies, generally in the context of a mission returning materials from such a body to the Earth.
- Earth microbiota cell division has not been observed below -18°C (Rummel et al., 2014)
- Report of genome replication at -20°C (Tuorto et al., 2014)
- COSPAR recommendations that Special Regions be in part based on temperatures above -25°C

## Interplay between PP policy, implementation, and exploration

- **Impossible to quantify cost of PP compliance (impact is not only in dollars)**
  - Engineering time on implementation and documentation
  - Exclusion of certain
  - Barrier to participation (perhaps, emerging instrument partners)?
  - Barrier to flying some off-the-shelf technologies?
  - Mission concepts never proposed (i.e., direct Cat 4c: <30 bacterial spores per lander)?
- **Potential for diminished science return or pace of discovery, in some cases**
  - Europa lander has a landed science payload of 42.5 kg
  - To end its mission (or react during a landing anomaly), it also has 11.8 kg of thermite incantatory material



## New discoveries with respect to bioload replication at Martian surface

- Gullies and Recurring Slope Lineae (RSLs)
  - Flow features on steep slopes
    - Gullies are on cold slopes (with CO<sub>2</sub> ice)
    - RSLs are associated with warm slopes
  - Perchlorate in RSLs reported (Ojha et al., 2015).
  - Perchlorate detection is likely a CRISM artifact (Leask et al., 2018)
  - RSLs are landslide events on a dusty surface
  - Numerous RSLs following M34 global dust storm (McEwen et al., 2020)

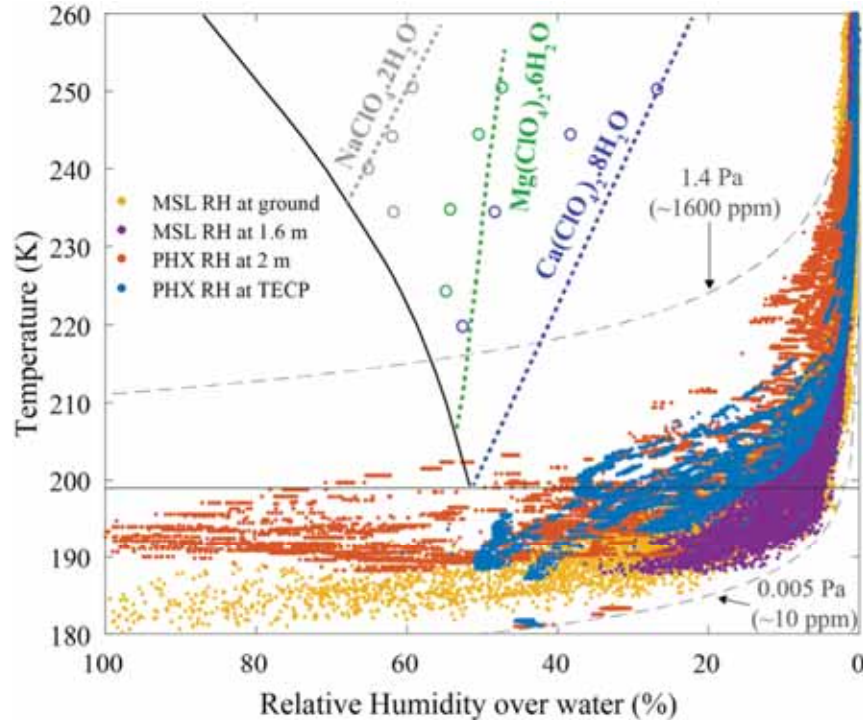


# Deliquescence

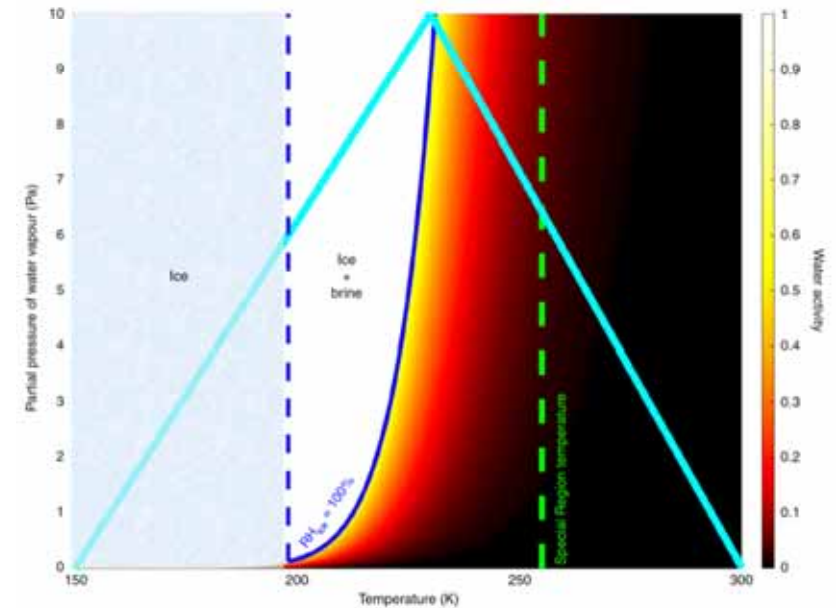
	Can salt likely <i>hydrate</i> under REMS surface conditions?	Can salt likely <i>dehydrate</i> under REMS surface conditions?
MgCl <sub>2</sub>	MAYBE	NO
Ca(ClO <sub>4</sub> ) <sub>2</sub>	YES	NO
CaCl <sub>2</sub>	NO	YES

**“Sodium perchlorate does not hydrate from the anhydrous form even after several hours of low temperature, high humidity conditions that were theoretically predicted to result in formation of NaClO<sub>4</sub>•H<sub>2</sub>O.”**

Gough et al., 2019



Fischer et al., 2019



**“Our results indicate that (meta)stable brines on the Martian surface and its shallow subsurface (a few centimeters deep) are not habitable because their water activities and temperatures fall outside the known tolerances for terrestrial life.”**

Rivera-Valentin et al., 2020

## Report of the Joint Workshop on Induced Special Regions

Michael Meyer<sup>a,\*</sup>, Corien Bakermans<sup>b</sup>, David Beaty<sup>c</sup>, Douglas Bernard<sup>d</sup>, Penelope Boston<sup>e</sup>, Vincent Chevrier<sup>f</sup>, Catharine Conley<sup>a</sup>, Ingrid Feustel<sup>g</sup>, Raina Gough<sup>h</sup>, Timothy Glotch<sup>i</sup>, Lindsay Hays<sup>e</sup>, Karen Junge<sup>j</sup>, Robert Lindberg<sup>k</sup>, Michael Mellon<sup>l</sup>, Michael Mischna<sup>d</sup>, Clive R. Neal<sup>m</sup>, Betsy Pugel<sup>a</sup>, Richard Quinn<sup>j</sup>, Francois Raulin<sup>n</sup>, Nilton Rennó<sup>o</sup>, John Rummel<sup>p</sup>, Mitchell Schulte<sup>a</sup>, Andrew Spry<sup>p</sup>, Pericles Stabekis<sup>q</sup>, Alian Wang<sup>r</sup>, Nathan Yee<sup>s</sup>

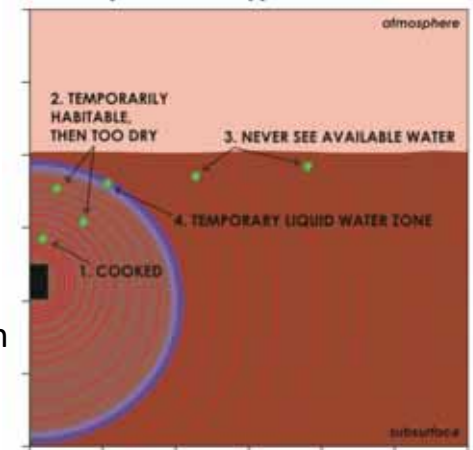
Finding: While a spacecraft on the surface of Mars may not be permitted to explore a Special Region during the prime mission, the sterilizing environment that is the martian surface and near surface would progressively clean the exposed spacecraft surfaces so that such SR investigations could be proposed for later in the extended mission.

Finding: While a buried RTG could produce an Induced Special Region, it would not pose a long-term contamination threat to Mars. One possible exception would be a migrating RTG in an icy deposit that reaches an existing natural Special Region.

Finding: Microbial transport away from subsurface Induced Special Regions is highly improbable.

### Spacecraft-induced special region

Shotwell, R. F., Hays, L. E., Beaty, D. W., Goreva, Y., Kieft, T. L., Mellon, M. T., ... & Spycher, N. (2019). Can an Off-Nominal Landing by an MMRTG-Powered Spacecraft Induce a Special Region on Mars When No Ice Is Present?. *Astrobiology*, 19(11), 1315-1338.



**FIG. 15.** Schematic cross-section summarizing the fate of microbes that may potentially be in and around the thermal anomaly. See explanations in text (Section 8.3) for further details.



# Martian meteorites considered in MMX PP classification

## **Restricted Versus Unrestricted Earth Return**

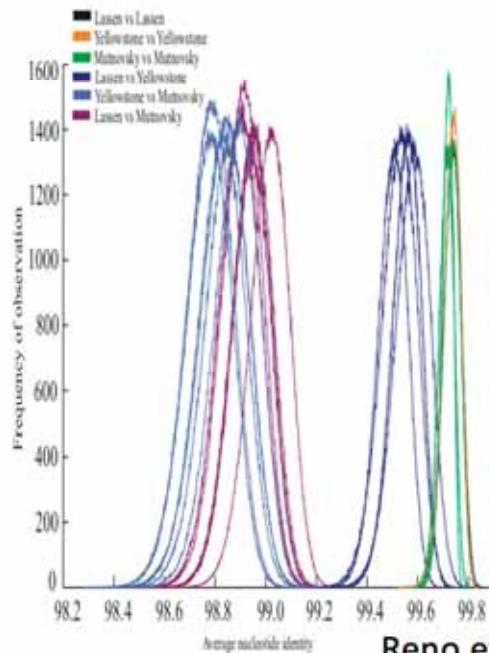
In determining whether samples returned from Phobos or Deimos should be classified as restricted or unrestricted Earth return, the committee considered the following factors:

- The work represented by the SterLim and JAXA teams can be considered as the state of the art, in regard to the modeling of the process of deposition of martian material on the surface of the martian moons. Nevertheless, significant deficiencies exist in understanding, and there remain experimental and computational challenges associated with the quantitative estimation of ejecta mass and temperature distributions. Even though issues still exist with the modeling work that was performed (see Chapter 2), the work is convincing in showing that there is significant sterilization introduced during the whole chain of events.
- The issue of desiccation on the surface of the martian moons for any present martian microbes was not considered. At temperatures above the freezing point of water, desiccation is bactericidal to even the most radiation-resistant microbes in a matter of months. (See “Sterilization by Radiation on Phobos/Deimos Surfaces,” in Chapter 2.)
- The relative influx of martian microbes from the Phobos/Deimos sample versus the natural influx of direct Mars-to-Earth transfer can be shown to be smaller by several orders of magnitude.

**Recommendation:** After considering the body of work conducted by the SterLim and JAXA teams, the effect of desiccation on the surfaces of the martian moons, and the relative flux of meteorite- to spacecraft-mediated transfer to Earth, the committee recommends that samples returned from the martian moons be designated unrestricted Earth return.

# Nature of microbial colonization

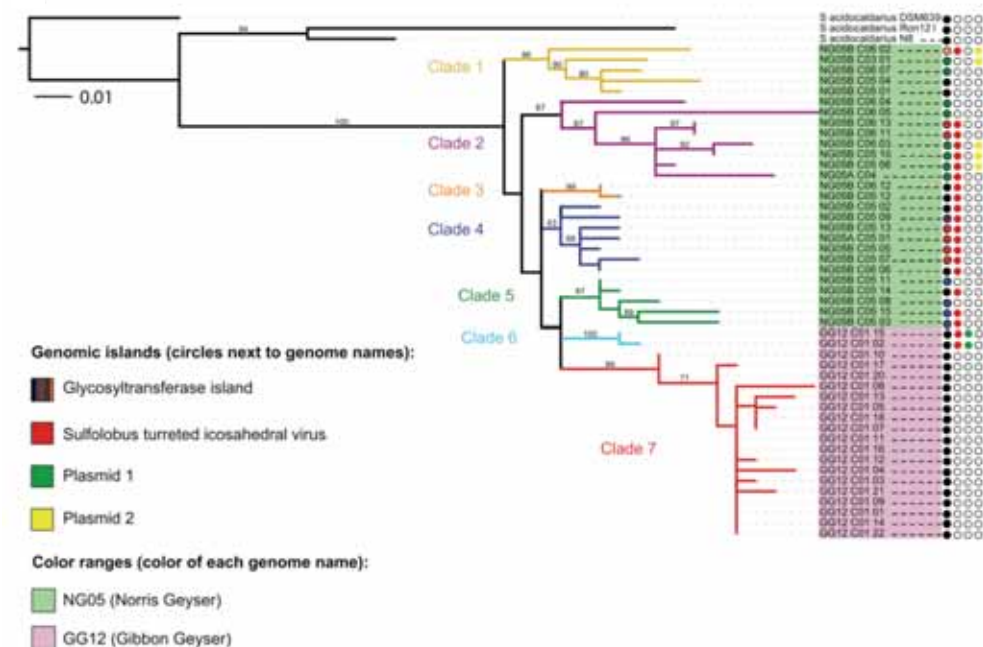
- There are mechanisms for global transport of microbes on Earth
- There appear to be significant barriers to replacement of endemic strains
  - Microbial specialization to specific fine-scale geochemistry
  - Endemic microbial populations are large compared to new arrivals



Divergence dates for *Sulfolobus islandicus* from 910,000 years ago for the North American and Mutnovsky (Kamchatka) populations. 140,000 years ago for divergences within the Mutnovsky volcanic complex.

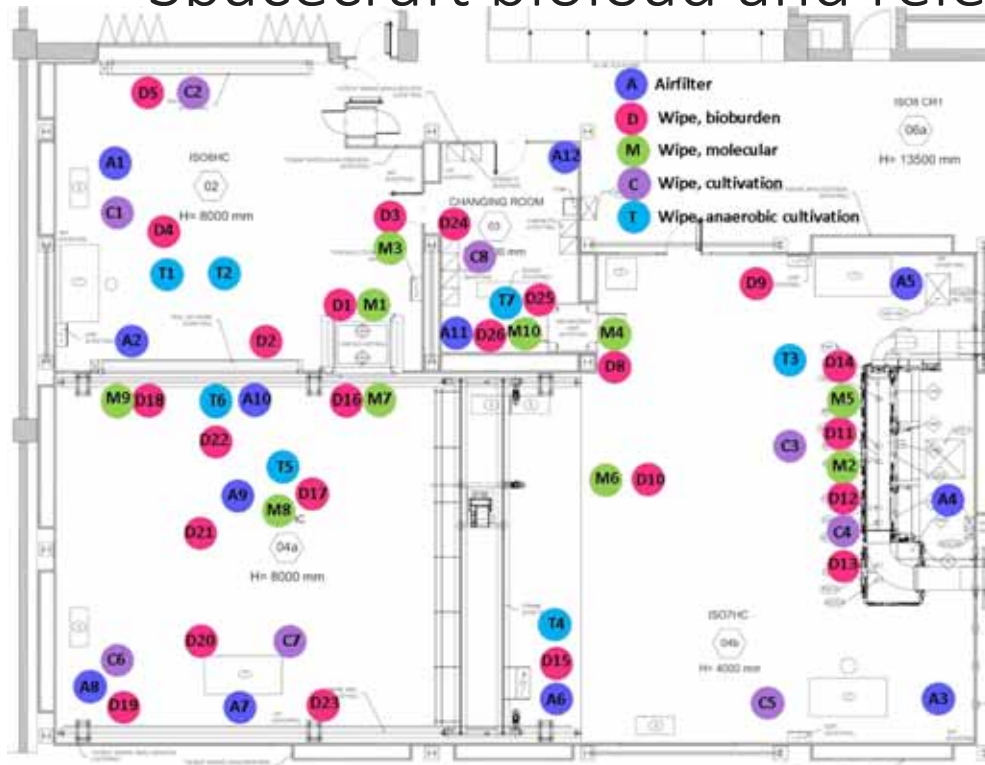
Reno et al., 2009

**Fig. 1.** Pairwise bANI for the 7 *S. islandicus* genomes. Comparisons between LNP (Lassen) strains (black), YNP (Yellowstone) strains (orange), and Mutnovsky strains (green) yield an average identity of 99.73%. Comparisons between North American strains (LNP vs. YNP, dark blue) give an average identity of 99.54%, whereas comparisons between each North American and Mutnovsky strain (magenta and light blue) yield an average identity of 98.89%.



At Yellowstone National Park, *Sulfolobus acidocaldarius* shows rare genomic events common in Norris Geyser field, but absent in nearly all Gibbon Geyser strains

# Spacecraft bioload and relevant PP microorganisms



- Bioload is mostly inside instrument electronics
- Spore counts is one approach to bioload quantification
- Molecular approaches provide insight into the metabolic capabilities of a bioload
- Modern planetary protection could leverage the genomic revolution to focus on microorganism potentially relevant to the planetary mission target
- Molecular biology provides means to differentiate Earth life from non-Earth life

## Microbial biodiversity assessment of the European Space Agency's ExoMars 2016 mission

[Kaisa Koskinen](#), [Petra Rettberg](#) ✉, [Rüdiger Pukall](#), [Anna Auerbach](#), [Lisa Wink](#), [Simon Barczyk](#), [Alexandra Perras](#), [Alexander Mahnert](#), [Diana Margheritis](#), [Gerhard Kminek](#) & [Christine Moissl-Eichinger](#) ✉

Koskinen et al., 2017



# New modern and/or flexible approaches

- Genetic and genomic approaches to focus on what is in a bioload  
(less of a focus on the size of the bioload)
- Flexibility in PP implementation
  - Traditional approaches (clean rooms, heat reduction, and IPA wipes)
  - Hydrogen peroxide vapor
  - UV LEDs
  - Consideration of bioload reduction during transit
  - Checklist or probability assessment or bioload reduction

# Summary

- PP is important and should enable exploration
- Planetary protection is a responsibility due to the non-interference provision and is intended to facilitate peaceful cooperative space exploration
- Bioload amplification is not possible in Mars Gullies and Recurring Slope Lineae
- Deliquescence at the Mars surface does not meet the criteria for bioload growth
- Induced special regions are likely transient
- Martian meteorites suggest the past transport of Earth microbes to Mars
- Microbial replacement of an endemic ecosystem requires  $>1$  cell
- A modern exploration strategy can leverage genetic and genomics
- Flexible approaches to PP implementation best enable exploration

Backup slides...



## Selected Findings & Recs: Mars (Humans)

Major Finding: Human missions to Mars will inevitably introduce orders of magnitude more terrestrial micro-organisms to Mars than robotic missions have done or will do.

Major Finding: Human missions to Mars will create new opportunities for science and exploration.

Major Finding: NASA's current policies for robotic Category V Restricted Earth Return from Mars appear to be unachievable for human missions returning from Mars.

Major Recommendation: NASA should invest in developing more informed, backward contamination PP criteria.



## Selected Findings & Recs: Mars (Humans)

Major Finding: PP planning for human missions to Mars and the communication of those plans to the public are presently immature.

Major Recommendation: NASA should begin, sooner rather than later, preparing for the public communication of all aspects of PP planning for human missions to Mars, and should pay special attention to public PP concerns, similar to NASA's proactive treatment of NASA missions involving radioisotope power systems.