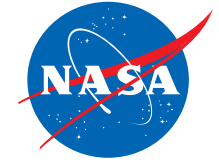


National Aeronautics and Space Administration

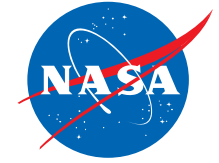


International Planetary Probe Workshop (IPPW)
Boulder, Colorado
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SPORES, VIABLE ORGANISMS, AND OTHER
TRIBULATIONS IN PLANETARY PROTECTION
REQUIREMENTS FOR MARS AND EUROPA

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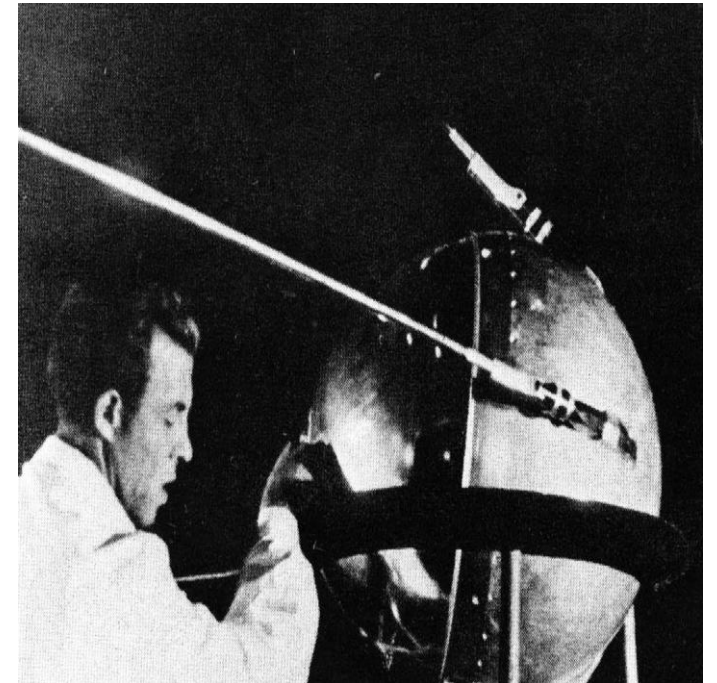
Brief History of Planetary Protection

International Council for Science founded in 1931 to promote international scientific activity in the different branches of science. Previously known as International Association of Academies (1899-1914) and International Research Council (1919-1931).

USSR launched Sputnik 1 in 1957, first artificial Earth satellite.

Committee on Space Research (COSPAR) chartered by the International Council in 1958 to promote and coordinate worldwide scientific research in space.

Committee on Peaceful Uses of Outer Space (COPUOS) set up by the United Nations General Assembly in 1959 to govern the exploration and use of space for the benefit of all humanity.

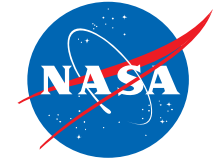




United States Signatory to United Nations Outer Space Treaty (OST)

NASA policies are consistent with OST stating that “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 Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt **appropriate measures** for this purpose.”

COSPAR maintains and updates planetary protection polices representing an international consensus standard for OST “**appropriate measures.**”



COSPAR Panel on Planetary Protection

The Panel on Planetary Protection (PPP) is concerned with biological interchange in the conduct of solar system exploration:

1. possible effects of contamination of planets other than the Earth, and of planetary satellites within the solar system by terrestrial organisms.
2. contamination of the Earth by materials returned from outer space carrying potential extraterrestrial organisms.



Validating Science and Protecting Earth's Biosphere

Planetary protection requirements ensure valid and safe scientific exploration for extraterrestrial life

NASA Objectives during robotic missions beyond Earth:

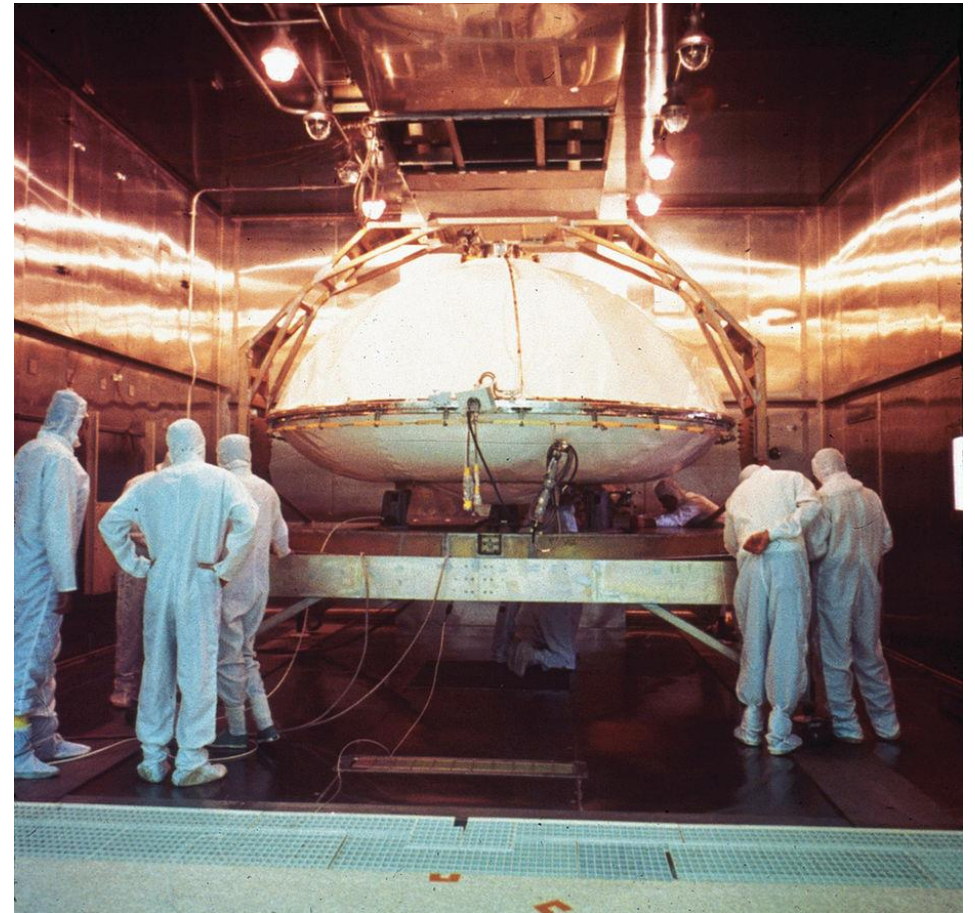
- (**VALID**) Avoid forward contamination of other worlds by terrestrial organisms carried on spacecraft.
- (**SAFE**) Prevent backward contamination of Earth by extraterrestrial life or bioactive molecules in samples returned for scientific study.



Viking-Level Bioload Is Still the Gold Standard

The Viking Mars orbiter/landers of the 1970's were sealed in a biobarrier and the entire assembly was dry heated to a temperature $>111\text{ }^{\circ}\text{C}$ for a period of 35 hours. The biobarrier/bioshield was designed to prevent recontamination after sterilization.

A Viking lander is loaded into an oven at the Kennedy Space Center. See article on Appropriate Protection of Mars by Conley and Rummel in *Nature Geoscience*, 2013.





Provisions for Robotic Extraterrestrial Missions

NASA Procedural Requirements
(NPR) 8020.12D

“All bioburden constraints are defined with respect to the number of aerobic microorganisms that survive a heat shock of 80°C for 15 minutes...



Blue tubs are filled with ice and water



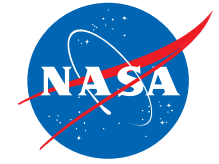


Provisions for Robotic Extraterrestrial Missions

NASA Procedural Requirements
(NPR) 8020.12D

...and are cultured on
Tryptic Soy Agar (TSA) at
32°C for 72 hours
(hereinafter “spores”).”

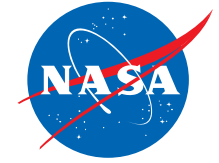




Temporary Assay Labs

Equipment, instruments and supplies at Vandenberg Air Force Base
in preparation for InSight launch

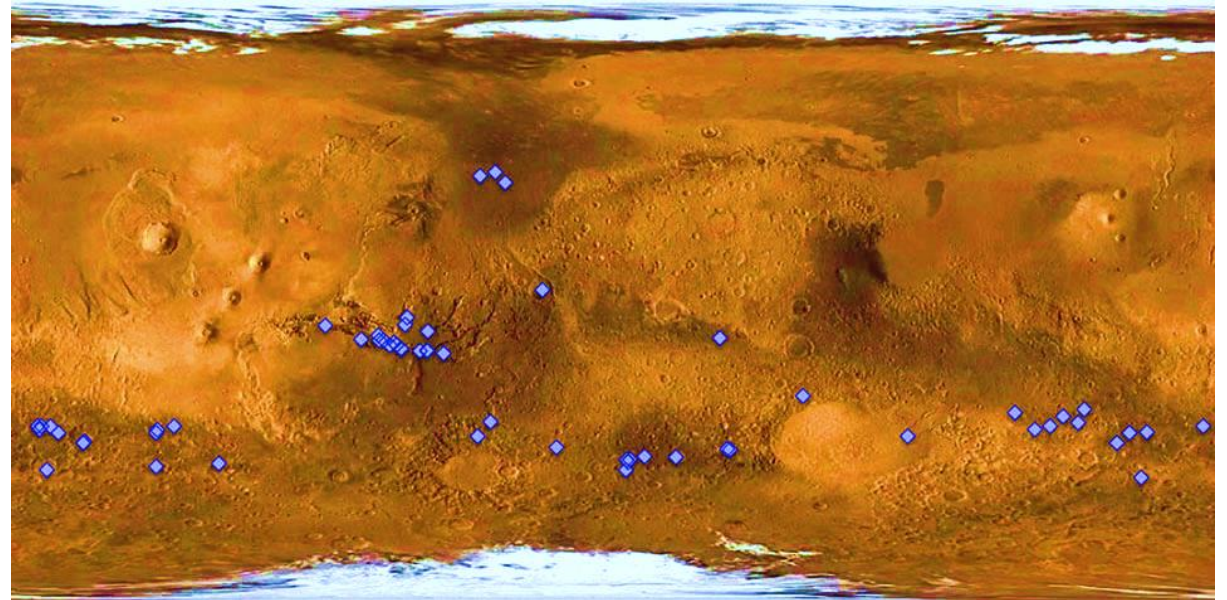




A Viable Organism Is One That Can Replicate

Special Regions on Mars are defined as areas or volumes within which sufficient water activity AND sufficiently warm temperatures to permit replication of Earth organisms may exist.

1. Lower limit for water activity: 0.5;
Upper limit: 1.0
2. Lower limit for temperature: -25C;
No Upper limit defined
3. Timescale over which limits apply:
500 years



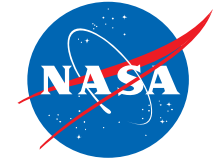
A New Analysis of Mars "Special Regions": Findings of the Second MEPEG Special Regions Science Analysis Group, 2014 Astrobiology



Non-Nominal Landing in a Special Region

If the probability of a non-nominal landing in a special region (including entry, descent, and landing) is greater than 0.01, then the entire landed system shall be sterilized to Viking post-sterilization levels: a surface biological burden level of $\leq 30^*$ spores and a total (surface, mated, and encapsulated) bioburden level of $\leq 1.5 \times 10^4$ spores*.

*This figure takes into account the occurrence of hardy organisms with respect to the sterilization modality



Mars 2020 Category IVb

Entire landed system restricted to a surface biological burden of ≤ 30 spores or to levels driven by the nature and sensitivity of the particular life-detection experiments with protection from recontamination.

OR

Subsystems involved in the acquisition, delivery, and analysis of samples used for life detection must be sterilized to above levels with a method of preventing recontamination of the sterilized subsystems and contamination of the material to be analyzed.

Notably, Category IVa lander systems not carrying instruments for the investigations of extant martian life shall be restricted to a surface biological burden level of $\leq 3 \times 10^5$ spores, and an average of ≤ 300 spores per square meter.



Europa and Enceladus

Flybys, orbiters and landers to icy satellites are held to probability less than 1×10^{-4} per mission of inadvertent contamination of an ocean or other liquid water body.



Europa and Enceladus

Calculation of probability shall include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

- a. Bioburden at launch
- b. Cruise survival for contaminating organisms
- c. Organism survival in the radiation environment adjacent to the target
- d. Probability of encountering/landing on the target, including spacecraft reliability
- e. Probability of surviving landing/impact on the target
- f. Mechanisms and timescales of transport to the subsurface
- g. Organism survival and proliferation before, during, and after subsurface transfer