Planetary Protection
Policy and Requirements

Catharine A. Conley,
NASA Planetary Protection Officer
On Earth, life is everywhere:

How do we ensure that we don’t find what we brought with us, when we go to explore somewhere else?
Over 50 Years of International Effort

- 1956, Rome: International Astronautical Federation meets to discuss lunar and planetary contamination
- Feb. 1958: International Council for Science (ICSU) forms committee on Contamination by ExtraTerrestrial EXploration
- June 1958: NAS establishes the SSB
- July 1958: Formation of NASA
- Oct. 1958: Formation of COSPAR by ICSU
- July 1958: Formation of UN-COPUOS
- 1963: NASA acquires the first ‘Planetary Quarantine Officer’ – on loan from the Public Health Service
International Agreements on Planetary Contamination/Protection

• The Outer Space Treaty of 1967:
  – Proposed to the UN in 1966
  – Signed by the US and Soviet Union in January 1967
  – Ratified by the US Senate on Apr. 25th, 1967

• Article IX:
  “...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...”

  “Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.”
  (http://www.state.gov/t/ac/trt/5181.htm)
Life on Earth Keeps Spreading

- Before *Deinococcus radiodurans*, we thought we knew how much radiation organisms could tolerate.
- Before *Desulforudis audaxviator* (and their nematode predators), we thought we knew where organisms could live.
- Organisms making do in 58 Million year old subsea sediments seem to wait around for a rather long time....
- What is the actual range (and duration) of conditions under which Earth Life can grow? Can tolerate? Can survive?
- Given that we know we keep learning more about life on Earth, how do we ensure that other planets are protected?

How do we compensate for what we don’t know?
Committee on Space Research (COSPAR) Planetary Protection Activities

- COSPAR maintains the international consensus planetary protection policy for the 1967 UN Space Treaty.
- COSPAR’s Planetary Protection Panel was formed to:
  - Develop, maintain, and promulgate planetary protection knowledge, policy, and plans to prevent the harmful effects of such contamination
  - Provide an international forum for exchange of information in this area through symposia, workshops, and topical meetings at COSPAR Assemblies
  - Inform the international community, e.g., the Committee on the Peaceful Uses of Outer Space (COPUOS) of the United Nations, as well as various other bilateral and multilateral organizations, of COSPAR decisions in this area.
  - Policy is revisited regularly through Panel activities.
COSPAR Planetary Protection Policy: 
*Protect Science, Protect the Earth*

- “The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized.”
  - *avoid forward contamination: don’t “discover” life we brought with us*

- “In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet or other extraterrestrial sources.”
  - *avoid backward contamination: don’t contaminate the Earth*

- “Therefore, for certain space-mission/target-planet combinations, controls on organic and biological contamination carried by spacecraft shall be imposed in accordance with directives implementing this policy.”
  - *tailor requirements by target location and mission type: don’t require unnecessary measures*
Preventing Contamination: 
A ‘Probabilistic’ Formulation

- In 1962, the SSB recommended to allow a $1 \times 10^{-4}$ probability of contamination per mission – anticipating many missions

The number of microbes that could survive on a planetary object was based on the initial contamination level $[N_0]$, and reduced by various factors:

$$N_{\text{final}} = N_{\text{initial}} \ F_1 \ F_2 \ F_3 \ F_\ldots$$

- $F_1$—Total number of cells relative to assayed cells ($N_{X_0}$)
- $F_2$—Bioburden reduction survival fraction, when applied
- $F_3$—Cruise survival fraction
- $F_\ldots$—Additional factors as appropriate for the mission scenario

- Factors are organized by mission phase, independent in time; iteration is necessary to demonstrate compliance
- 'Probability of growth' on Mars, during Viking, was estimated to be $1 \times 10^{-6}$ – we now know it’s a lot closer to 1...
Reduction factors may include:

- Microbial burden at launch (number and type)
  - *Reduction may be necessary to meet 1x10^-4*

- Survival of contaminating organisms during cruise
  - *Determine orbital trajectory and spacecraft failure modes*

- Organism survival in the radiation environment
  - *Sets time window: sterility assumed upon 7 Mrad total dose*

- Probability of impacting/landing on the target body
  - *Derived from spacecraft reliability and orbital trajectory*

- Probability of surviving impact/landing
  - *Large fraction of high-velocity impacts sterilize hardware*

- Mechanisms of transport to the subsurface
  - *Not yet well-understood; new data change models*

**Assumptions must be conservative**
COSPAR Policy: Planetary Protection Mission Constraints

- Depend on the nature of the mission and on the target planet

- Assignment of categories for each specific mission/body is to take into account current scientific knowledge based on recommendations from scientific advisory groups

- Examples of specific measures include:
  - Constraints on spacecraft operating procedures
  - Spacecraft organic inventory and restrictions
  - Reduction of spacecraft biological contamination
  - Restrictions on the handling of returned samples
  - Documentation of spacecraft trajectories and spacecraft material archiving

W. Peet, 1967
Alles sollte so einfach wie möglich gemacht werden, aber nicht einfacher.

Albert Einstein

Everything should be made as simple as possible, but not simpler.
NASA Planetary Protection Policy

- The policy and its implementation requirements are embodied in NPD 8020.7G (approved by NASA Administrator)
  - The Planetary Protection Officer acts on behalf of the Associate Administrator for Science to maintain and enforce the policy
  - NASA obtains recommendations on planetary protection issues (requirements for specific bodies and mission types) from the National Research Council’s Space Studies Board
  - Advice on policy implementation is obtained from the NAC Planetary Protection Subcommittee

- Specific requirements for robotic missions are embodied in NPR 8020.12D (approved by SMD Associate Administrator)
  - Encompasses all documentation and implementation requirements for forward and back-contamination control

- A formal requirements document for human missions is in draft

- Complies with COSPAR policy: NASA supports international missions only if COSPAR policy is followed
NASA Planetary Protection Policy
(from NPD 8020.7G)

- “The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized.”
  - Preserves science opportunities directly related to NASA’s goals, and can support certain ethical considerations; originally recommended to NASA by the NAS in 1958
  - Preserves our investment in space exploration
  - Can preserve future habitability options

- “The Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet.”
  - Preserves Earth’s biosphere, upon which we all depend...

- Assignment of categories for each specific mission/body is to “take into account current scientific knowledge” via recommendations from advisory groups, “most notably the Space Studies Board.”
Role of the Planetary Protection Officer (NPD 8020.7G)

Designee of the SMD Associate Administrator, responsible for planetary protection:

- Prescribes standards, procedures, and guidelines applicable to all NASA organizations, programs, and activities to achieve policy objectives
- Certifies to the SMD AA that missions are compliant
  - Before launch
  - If returning samples, before initiating return and again before Earth entry
- Conducts reviews, inspections, and evaluations of personnel, plans, facilities, equipment, procedures, and practices of NASA organizations and contractors
- Keeps the SMD AA (and, as appropriate, the Administrator) informed of developments, and takes action to ensure compliance with applicable NASA policies and requirements
“Current Scientific Knowledge” (NPD 8020.7G)

- Planetary Protection constraints “will take into account current scientific knowledge about the target bodies through recommendations from both internal and external advisory groups”
  - “Most notably” the Space Studies Board of the NRC
    - provides recommendations on high-level policy and requirements
  - Internally, the Planetary Protection Subcommittee of the NASA Advisory Council (formerly the Planetary Protection Advisory Committee)
    - provides programmatic advice and detailed advice on implementation for individual missions
    - includes representatives from other US agencies and international space agencies
ESD Planetary Protection Policy

- Policy described in ESA/C(2007)112 (Council Level)
  - Avoid interplanetary contamination when the Agency is carrying out activities in outer space, mindful of Member States’ corresponding obligations in accordance with Article II of the ESA Convention
  - States compliance with the COSPAR Planetary Protection Policy
  - Advice on planetary protection issues is obtained from the ESA Planetary Protection Working Group (PPWG); additional ad-hoc advice is provided by the European Science Foundation (ESF)

- Requirements described in ESSB-ST-PP-001 (ESA)
  - The Planetary Protection Officer acts on behalf of the Head of the Product Assurance & Safety Department
  - Specifies planetary protection requirements for spaceflight missions

- The European Cooperation for Space Standardization maintains technical standards/procedures to implement ESSB-ST-PP-001
  - Three standards available: ECSS-Q-ST-70-53, 55, and 58
  - Three additional standards released by 2011
# NASA/ESA/COSPAR Policy: Planetary Protection Mission Categories

<table>
<thead>
<tr>
<th>PLANET PRIORITIES</th>
<th>MISSION TYPE</th>
<th>MISSION CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Any</td>
<td>I</td>
</tr>
<tr>
<td>B</td>
<td>Any</td>
<td>II</td>
</tr>
<tr>
<td>C</td>
<td>Flyby, Orbiter</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>Lander, Probe</td>
<td>IV</td>
</tr>
<tr>
<td>All</td>
<td>Earth-Return</td>
<td>“restricted” or “unrestricted”</td>
</tr>
</tbody>
</table>

- A: Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted.
- B: Of significant interest relative to the process of chemical evolution, but only a remote chance that contamination by spacecraft could jeopardize future exploration. Documentation is required.
- C: Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which could jeopardize a future biological experiment. Substantial documentation and mitigation is required.
Planetary Protection Requirements
(NPR 8020.12D)

- Assignment of categories for each specific mission/body is to “take into account current scientific knowledge” via recommendations from scientific advisory groups.
- Categorization depends on the nature of the mission and on the target planet.
- Examples of specific constraints include:
  - Limitations on spacecraft operating procedures
  - Inventory of spacecraft hardware and materials
  - Documentation of spacecraft trajectories and material archiving
  - Reduction of spacecraft biological contamination
  - Restrictions on the handling of returned samples
- Probabilistic requirements allow derivation of numerical limits on microbial contamination pre-launch
Category III/IV Requirements for Icy Bodies

Category III and IV. Requirements for flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of a subsurface ocean to less than $1 \times 10^{-4}$ per mission. These requirements will be refined in future years, but 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 local radiation environment
- Probability of surviving landing on the object
- The mechanisms of transport to a potential subsurface ocean
- Organism survival and proliferation before, during, and after subsurface transfer
Category III/IV Requirements for Mars

Category III. Mars orbiters are required either to meet orbital lifetime requirements* or to achieve bioburden levels equivalent to the Viking lander pre-sterilization total bioburden.

*Defined as 20 years after launch at greater than or equal to 99% probability, and 50 years after launch at greater than or equal to 95% probability.

Category IV for Mars is subdivided into IVa, IVb, and IVc:

Lander systems not carrying instruments for the investigations of extant martian life are restricted to a biological burden no greater than Viking lander pre-sterilization levels (Cat. IVa). Lander systems searching for life (Cat. IVb) or entering special regions (IVc) must meet Viking post-sterilization levels.
Category IV Requirements for Mars

Category IV for Mars is subdivided into IVa, IVb, and IVc:

Category IVb. For lander systems designed to investigate extant martian life, all of the requirements of Category IVa apply, along with the following requirement:

- The entire landed system must be sterilized at least to Viking post-sterilization biological burden levels, or to levels of biological burden reduction driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent
  
  OR

- The subsystems which are involved in the acquisition, delivery, and analysis of samples used for life detection must be sterilized to these levels, and a method of preventing recontamination of the sterilized subsystems and the contamination of the material to be analyzed is in place.
PPO Monitoring Activities

- Evaluate pre-project studies
- Provide formal mission categorization
- Establish detailed requirements definition
- Assist with implementation strategies
- Perform document review and approval
- Monitor project through formal and informal PP reviews
  - Biological assays (verification)
  - Recontamination analyses
  - Project-specific analyses and reports
  - Requests for waivers/deviations (not easy!)
  - Certification of compliance for launch

- Following launch, spacecraft operations are monitored, including review and approval of extended mission operations as well as final disposition of hardware
Some documentation required for all extraterrestrial planetary missions – not required for heliocentric or Earth orbiting missions

Schedule and Contents per NPR 8020.12D

Required documents and contents dependent on mission category

Additional mission-specific documentation and requirements can be imposed/negotiated during project interactions with PPO
# Documents Required for Categories I-IV

## Documentation
- Certification of Category I mission request: No further documentation
- Category assignment request
- PP Plan draft
- PP Plan approved
- PP Implementation Plan (III-IV only)
  - Subsidiary plans (III-IV only)
- Prelaunch PP Report
- Postlaunch PP Report
- Extended Mission PP Request/Report
- End of Mission PP Report

## Delivery to NASA PPO
- Phase A (Mission/Systems Definition)
- During Phase A
- Early in Phase B
- By Preliminary Design Review
- By Critical Design Review
- 90 days pre-launch (mandatory review 120-90 days pre-launch)
- 60 days post-launch
- > 60 days prior to planned End of Mission
- 60 days after formal End of Mission
Planetary Protection Makes Sense:

We do want to do science on other objects...

So nobody should trash the place (or samples) before we have a chance to look!

Bill Peet, 1974