Planetary Protection for Jupiter's Icy Moons

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Planetary Protection Policy
(NPD 8020.7E)

It is NASA's policy to:

- Preserve planetary conditions for future biological and organic constituent exploration
- To protect Earth and its biosphere from potential extraterrestrial sources of contamination

Complies with Article IX of the Outer Space Treaty of 1967

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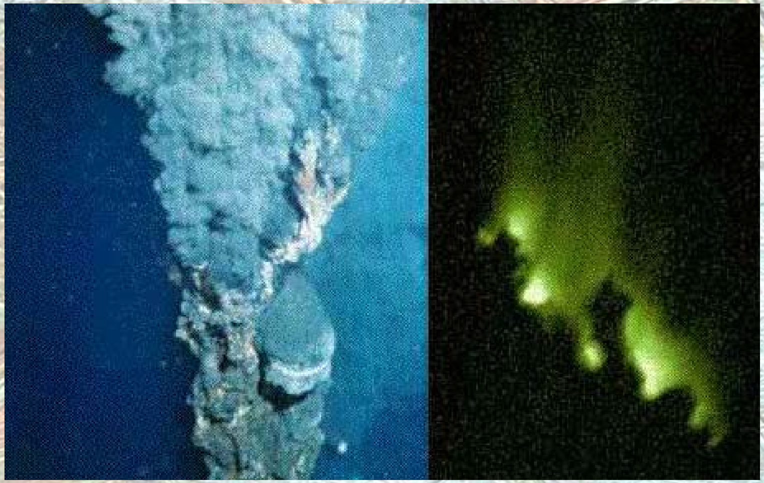
Planetary Protection Philosophy

A central tenet MUST be a presumption of ignorance:



It isn't that we expect to find these things out there—

It's that we never expected to find them HERE!

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Background Documents

- NASA Policy Document (NPD) 8020.7E establishes planetary protection policy for the Agency
  - "Specific constraints imposed on spacecraft involved in solar system exploration will depend on the nature of the mission and the identity of the target body or bodies. These constraints will take into account **current scientific knowledge** about the target bodies through **recommendations from both internal and external advisory groups**, but most notably from the **Space Studies Board** of the National Academy of Sciences."
- NPG 8020.12B, "Planetary Protection Provisions for Robotic Extraterrestrial Missions" establishes implementation requirements for missions based on mission category
- COSPAR (an interdisciplinary committee of the International Council for Science–ICSU) maintains an international consensus planetary protection policy (current version dated 10/02)
- PP requirements for Jupiter Icy Moons Orbiter as of now are based on:
  - NRC/SSB report on "Preventing Forward Contamination of Europa," 2000, which provides a framework for future decisions
  - NRC/SSB/COMPLEX letter of 28 June 2000 on Galileo disposal
  - Additional studies and data to be determined between now and JIMO PDR

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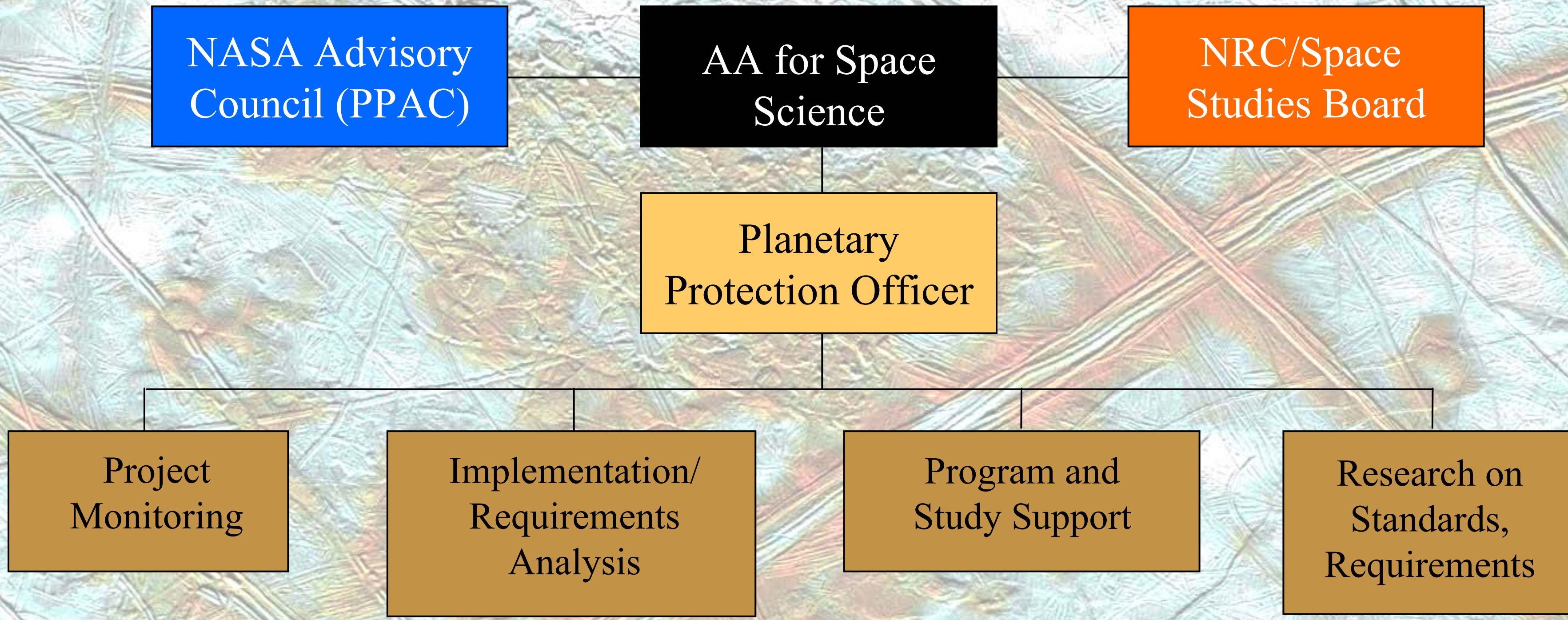
NASA Planetary Protection Office Overview



<u>Project Monitoring</u>

- Plans, reports, status
- Implementation assurance

<u>Implementation/Requirements Analysis</u>

- Project plan analysis and independent review
- Implementation strategies and outcomes

<u>Program and Study Support</u>

- Workshops and working groups
- Committee staff and liaison
- Advanced planning

<u>Research on Standards, Requirements</u>

- Project-common methods/qualifications
- Implications of exobiological findings

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Preventing the Forward Contamination of Europa

SSB 2000

- For every mission to Europa, the probability of contaminating a possible europan ocean with a viable terrestrial organism at any time in the future should be less than 10^{-4} per mission.
- Current cleaning and sterilization techniques are satisfactory to meet the needs of future space missions to Europa.
- Current culture-based method used to determine the bioload on a spacecraft should be supplemented by screening tests for specific types of extremophiles, such as radiation-resistant organisms.
- Modern molecular methods, such as those based on the polymerase chain reaction (PCR), may prove to be quicker and more sensitive to detect and identify biological contamination than NASA's existing culturing protocols.
- Studies should be conducted to improve knowledge of Europa, and define the issues related to minimization of forward contamination, including:
  - Ecology of clean room and spacecraft-assembly areas, with emphasis on extremophiles, such as radiation-resistant microbes
  - Detailed comparisons of bioload assay methods
  - Desiccation- and radiation-resistant microbes that may contaminate spacecraft
  - Autotroph detection techniques; and
  - Europa's surface environment and its hydrologic and tectonic cycles.

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Preventing the Forward Contamination of Europa

SSB's Example Calculation of Probability of Contamination

The number of organisms of type X that will Survive on Europa is based on the initial contamination level [N_{X0}] and various survival factors:

$$N_{Xs} = N_{X0} F_1 F_2 F_3 F_4 F_5 F_6 F_7$$

F_1—Total Number Of Cells Relative To Cultured Cells
F_2—Bioburden Reduction Treatment
F_3—Cruise Survival Fraction
F_4—Radiation Survival
F_5—Probability Of Landing At An Active Site
F_6—Burial Fraction
F_7—Probability That An Organism Survives And Proliferates

Where the organisms of type X are defined as:

- Type A. Typical, common microorganisms of all types (bacteria, fungi, etc.);
- Type B. Spores of microorganisms, which are known to be resistant to insults (such as desiccation, heat, and radiation);
- Type C. Spores which are especially radiation-resistant; and
- Type D. Rare, but Highly Radiation Resistant non-spore microorganisms (e.g., *Deinococcus radiodurans*).

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NASA/COSPAR Policy:
Planetary Protection Mission Categories

PLANET PRIORITIES		MISSION TYPE	MISSION CATEGORY
A	Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted (no requirements).	Any	I
B	Of significant interest relative to the process of chemical evolution, but only a remote chance that contamination by spacecraft could jeopardize future exploration.	Any	II
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.	Flyby, Orbiter	III
		Lander, Probe	IV
All	Any Solar System Body	Earth-Return	V

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Category III/IV Requirements for Europa

Category III and IV. Requirements for Europa flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of an europan ocean to less than 1×10^{-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 radiation environment adjacent to Europa
- Probability of landing on Europa
- The mechanisms of transport to the europan subsurface
- Organism survival and proliferation before, during, and after subsurface transfer

Category III/IV Reqs. for Europa (cont.)

- Preliminary calculations of the probability of contamination suggest that bioburden reduction will likely be necessary even for Europa orbiters (Category III) as well as for landers, requiring the use of cleanroom technology and the cleanliness of all parts before assembly, and the monitoring of spacecraft assembly facilities to understand the bioload and its microbial diversity, including specific problematic species.
- Specific methods should be developed to eradicate problematic species. Methods of bioburden reduction should reflect the type of environments found on Europa, focusing on Earth extremophiles most likely to survive on Europa, such as cold and radiation tolerant organisms (SSB 2000).

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NRC/SSB/COMPLEX Letter of 28 June 2000 on Final Disposition of Galileo

- There is no planetary-protection-related objection to the disposal of Galileo by intentional or unintentional impact with Io or Jupiter.
- There are serious planetary-protection objections to the intentional or unintentional disposal of Galileo on Europa. Qualitative limits on acceptable probabilities of contamination are contained in the recent report of the Task Group on the Forward Contamination of Europa.
- The planetary-protection implications of the intentional or unintentional impact of Galileo with Ganymede or Callisto are intermediate in the broad range between those for disposal on Io and for disposal on Europa
  - The biological potential of Ganymede cannot be shown to be zero
  - Callisto may have an ocean, but lack a biologically useful energy source
  - Prudence dictates a preference for end-of-mission scenarios that involve a minor risk of impact with either Ganymede or Callisto.

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Likely Impositions on JIMO

"Protect and Preserve"

Specific measures may include:

- Reduction of spacecraft biological contamination
  - Clean the spacecraft from the inside, out (microbe-life ≈ silicon-life)
- Constraints on spacecraft operating procedures
  - Adopt fail-friendly long-term orbits
- Spacecraft organic inventory and restrictions
  - Know/reduce damage if this doesn't work out
- Restrictions on the handling of returned samples
  - Later! (but watch that dynamic chaos....)
- Documentation of spacecraft trajectories and spacecraft material archiving
  - Well, yeah....This is a Government policy, after all....

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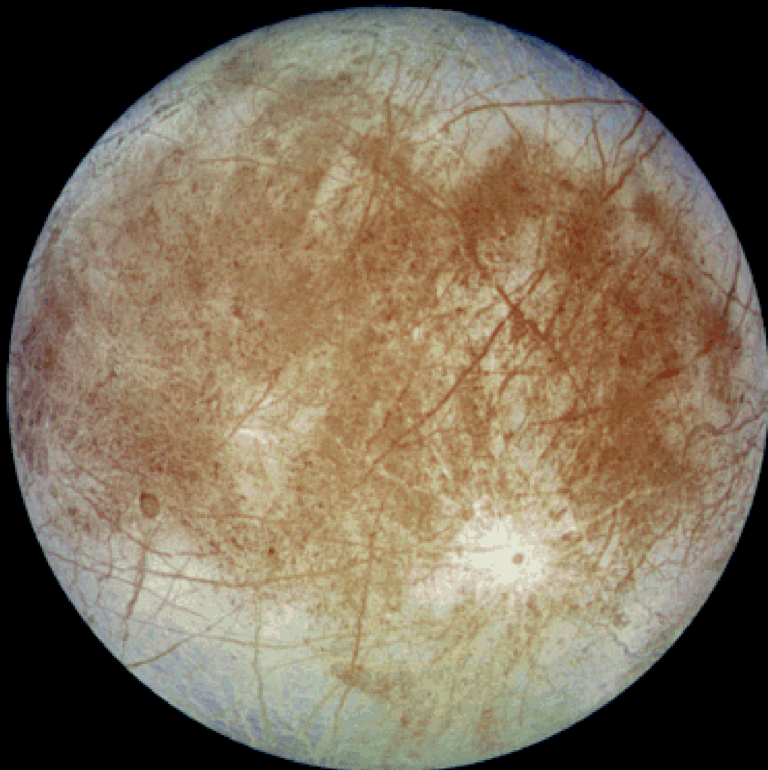
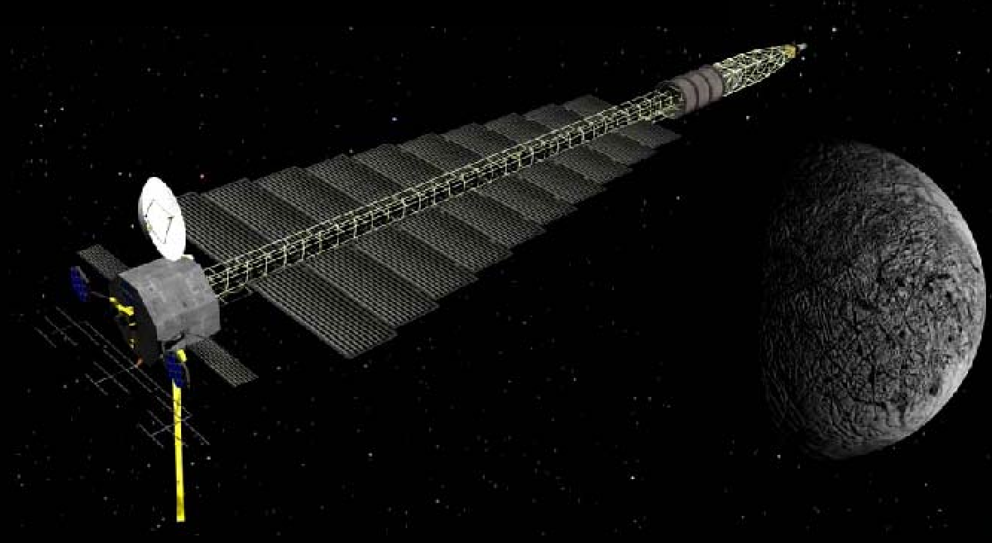


Questions??

Comments??



Coffee!