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Implementing Planetary Protection—Some Experiences and Perspective

Briefing to

NAS Committee to Review the Planetary Protection Policy Development Processes

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In consultation with a large number of colleagues, both inside and outside of JPL, and inside and outside of Mars exploration.

1967 Outer Space Treaty

"States 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."

Some problems:

- The terms "harmful", "adverse", and "appropriate" are not defined, and are a matter of interpretation.
- What are reasonable risk standards?
- No time limit specified
- Policy derived from this statement has oddities

Context: What NASA Is Trying To Do

1. Send missions, on behalf of the public, to explore the Solar System (and beyond).
2. Thus, there is a practical dimension to the rationale for planetary protection. The planets could be made completely safe if we stopped flying missions—this is not our objective.
3. Since we are actively engaged in the process of exploration/discovery, our knowledge base continually increases, and our policies/requirements need to continuously evolve.

“Harmful”: Target Objects (Forward PP)

1. Harmful Forward Contamination would include the loss of the ability to study a target object in its natural state.
2. Expressed differently, avoid the delivery of Earth organisms by one mission that propagate via natural processes to contaminate a different site that would be investigated for the presence of indigenous life by a second mission.
3. It is a particularly high priority to avoid inoculating globally-communicating habitable (by Earth organisms) environments.
4. However, not all spacecraft-related contamination events are associated with globally-communicating habitable environments. Would loss of the ability to study specific regions at a local scale be considered unacceptably harmful?

“Harmful”: Forward PP and Human Missions

1. Our advance planning teams cannot anticipate the Forward PP requirements for a human mission to the martian surface reliably enough to be able to plan and budget development of the mission concept, and planning the associated technology development and precursor mission programs.
2. For Mars, do we know enough now to establish “permissible zones” at the surface, where human landings with much higher contamination loads could be permitted without causing global harm (to within reasonable risk standards)?
3. As part of the subject of ISRU for a potential future human mission, how risky would accessing a local ice deposit on Mars to characterize / study / use it be? What is the risk of transport pathways that would have global significance?

“Harmful”: Earth (Back PP)

1. Harmful contamination of Planet Earth would include the uncontrolled introduction of live extraterrestrial organisms into a terrestrial environmental niche where they propagate and potentially colonize.
2. For potential sample return missions from relevant target bodies, Earth needs to be protected to within reasonable risk standards from the small but non-zero chance that an extraterrestrial lifeform is present in one or more of the returned samples.

Adequately discussed yesterday

“Harmful”: “Round-trip” PP

1. Would the trace Earth-sourced biological/organic contamination that would make the round trip on sample return missions cause harmful biological effects to the Earth?
   - With modern instrumentation, our ability to measure is greater than our ability to clean; thus detectable Earth-sourced contamination is a certainty on returned samples (see Summons et al. 2014). A key strategy is recognition of contamination, not quantitative elimination.
   - Knowledge of such contamination is critical to sample science, as part of assessing the possibility of life as precisely and accurately as possible. This is an area where PP concerns and science interests overlap.
   - This is a risk tolerance issue: Even with extraordinary effort, like many scientific experiments, the risk of an ambiguous result is non-zero. How much effort/expense is justified?
   - Avoiding false positives is a science concern not a PP concern--there is no threat to earth from a round-trip earth organism (only a threat in confounding the science). **See Slide #12**.

Defined time period

1. Some timeframe is necessary to choose policies/ implementations that are supported by our predictive capabilities.
2. Relevant protection times—Forward PP
    - Past proposed timescale for Mars (e.g. Viking 50 years) was found to be too short to complete the exploration necessary to answer the life question.
    - Is the figure of 500 years proposed by the most recent study on Mars Special Regions (Rummel et al. 2014) reasonable?
    - The number used for Dawn PP and assessment of the stability of the spacecraft orbit around Ceres was 300 years.
3. Relevant protection times—Back PP
    - There is no rationale for a time limit on Back PP.

Reasonable risk standards: Forward PP

1. How much risk are we willing to accept?
   - The only way to take the risk to zero is not to launch. The question is how much risk is acceptable, not whether there is risk.
2. We cannot know in advance everything we want to know about the environmental habitability of target objects—we need to explore to know.
3. Thus, would it be possible to sacrifice some locations as part of the exploration process with reasonable expectation of it not having a global effect?
   - As a Mars example, is it possible to sacrifice an RSL as part of its investigation? Is there a reason to believe that RSL in one part of Mars are in communication with RSL in a completely different place?
4. Scale of movement. How far could microbe-containing particles move before they constitute a threat to the global system (e.g.,100 m?)?

Reasonable risk standards: Back PP

1. How do we determine that "the risk is acceptably low"?
   - Cost, risk, and consequence can all be traded against each other in reaching a final exploration strategy.
   - Who will determine how low is low enough?
2. Evaluation of samples.
   - Is there a pathway to evaluate the biohazard risk of Mars samples without completely consuming them (statistical significance of a subsample)?
   - How extreme should the measures be for the sterilization of samples that need to be investigated outside of containment?

Protecting Science?

- The questions related to evaluating the possibility of extra-terrestrial life require application of the full scientific process: multiple working hypotheses, L1 requirements, data, interpretations, debate, peer review, discussion-reply, re-analysis, re-debate, as many loops as needed . . .
  - False positives are a certainty in astrobiology science—this is not something we need to protect against. This is part of the scientific process.
  - From our perspective PP involvement in science objectives/questions adds confusion.
- NASA's mission formulation process includes methods for adding L1 science-related requirements to flight projects, and ensuring that these requirements are taken seriously.
- The science of Astrobiology cares deeply about both <u>contamination control</u> (keeping the total quantity of contamination below certain levels) and <u>contamination knowledge</u> (characterizing the residual contamination that remains). These are fundamental requirements.

Some Mechanical Issues

1. It doesn't make sense to us to have intention-dependent requirements (e.g., differences between IV a, b).
2. It also doesn't make sense to have requirements that specify implementation (e.g., define a cleanliness requirement, should not matter how it is achieved).
   - The engineers need requirements that describe a system's objective or end state, from which they can optimize the design and verify the implementation.
3. There are recurring disputes between the S/C providers and the PP Office about the cost of implementing actual or potential PP requirements. ***The science teams get caught in the middle of a tug of war that helps no one.***

Implementing Missions: Perspective

- NASA missions are tightly cost-controlled. It is important that all requirements - including PP - are defined up front, early in the project life–cycle, so that budget and scope can be aligned. Late addition of PP requirements has been problematic for mission implementation.
- There are ambiguities in how NASA's procedures relating to requirements for projects and programs (7120.5) integrate with separate requirements coming from PP (8020.12). This creates a situation where direction is coming from two different sources—a root cause of the twin Mars mission failures (MCO and MPL) in 1999.
- There is a perception that "too much of the policy has been drawn from the 'philosophy' side without enough consideration of the 'practice'".
- Are we overly risk averse? How do we collectively find the right balance between risk, consequences, and cost? Who decides this balance?
- From one scientist: "There is too much infighting and not enough collaboration or creativity being used to address this important issue."
- **To enable exploration, technically and financially balanced solutions need to be in the option space.**

Summary of Suggestions

1. PP attention to “round trip contamination” (contamination that originated from Earth coming back to Earth) confuses the scientific investigation of returned materials, a science-driven question, with protecting the planets. This is causing considerable unnecessary conflict.
2. PP should be periodically reviewed/modified, and with a wider number of people involved. Our interpretations of what constitutes “harmful” and what constitutes “appropriate” risk change with time. The current perception is that PP is a closed shop, and that too few people control the system.
3. Current PP restrictions may not provide a plausible pathway for implementing a human-based Mars surface mission. This is a fundamental part of NASA’s (and other entities’) forward vision.
4. It is damaging to the mission development process when requirements come in late, especially after the mission cost has been agreed to. All requirements need to be associated with corresponding resources.