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Planetary protection for human exploration of Mars

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ABSTRACT

Human astronauts have unique capabilities that could greatly facilitate scientific exploration of other planets. However, when searching for life beyond Earth, these capabilities can be utilized effectively only if the biological contamination associated with human presence is monitored and minimized. This is termed planetary protection, and is a critical element in human exploration beyond Earth. Planetary protection must be incorporated from the earliest stages of mission planning and development, to ensure proper implementation. Issues involve both "forward contamination", the contamination of other solar system bodies by Earth microbes and organic materials, and "backward contamination", the contamination of Earth systems, including astronauts, by biological hazards or potential alien life. Conclusions from a number of international workshops held over the last six years recognize that some degree of forward contamination associated with human astronaut explorers is inevitable. Nevertheless, when humans are exploring space the principles and policies of planetary protection, developed by COSPAR in accordance with the 1967 Outer Space Treaty, still apply. Implementation guidelines include documenting and minimizing contamination of the exploration targets, control at the most stringent levels for locations in which Earth life might grow, and protection of humans from exposure to untested planetary materials. Preventing harmful contamination of the Earth must be of the highest priority for all missions.

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1. Introduction

When searching for life beyond Earth, the unique capabilities of human astronauts can be utilized effectively only if biological contamination associated with human presence is understood and controlled. Regulating biological contamination during planetary exploration is termed planetary protection, and will be a critical element in the human exploration of other solar system bodies. Planetary protection must be incorporated from the earliest stages of mission planning and development, to ensure proper implementation. Issues of concern to planetary protection involve both "forward contamination", which is the contamination of other solar system bodies by Earth microbes and organic materials, and "backward contamination", which is the contamination of Earth systems by potential alien life. Forward contamination involves contamination that might invalidate current or future scientific exploration of a particular solar system body, and that might disrupt the planetary environment or a potential endogenous (alien) ecosystem. Backward contamination involves the potential for harmful contamination of the Earth, and for human missions includes the possible immediate and long-term effects on the health of the astronaut explorers from possible biologically-active materials encountered during exploration.

A number of national and international workshops held over the last six years [1–4] have generated a consensus regarding planetary protection policies and

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requirements for human missions to Mars, and a 2007 workshop held by NASA has considered the issues and benefits to planetary protection that might be offered by a return to the Moon [5]. Conclusions from these workshops recognize that some degree of forward contamination associated with human astronaut explorers is inevitable. Nevertheless, the principles and policies of planetary protection, developed by the Committee on Space Research (COSPAR) in accordance with the 1967 Outer Space Treaty, can and should be followed when humans are exploring space.

Implementation guidelines include documenting and minimizing contamination of the exploration targets, protection at the most stringent levels for any target locations in which Earth life might grow, protection of humans from exposure to untested planetary materials, and preventing harmful contamination of the Earth as the highest priority of all missions. These principles should be incorporated in frameworks for future international missions of human exploration. It would be a tragic medical accident were an astronaut on the way to Mars get sick of unknown causes. It would be far more tragic, and of significant concern for planetary protection, should one of several astronauts become ill on the return from Mars to Earth, without sufficient medical information to determine why.

2. International basis for planetary protection policy

Planetary protection entered into international law with Article IX of the 1967 Outer Space Treaty, which states in part that:

"…parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exp loration 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…" [6].

COSPAR is an interdisciplinary committee of the International Council for Science that maintains an international consensus planetary protection policy [7], which serves as the standard for biological contamination avoidance under the 1967 Outer Space Treaty. COSPAR, along with the International Astronautical Foundation, consults with the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) in assessing "harmful contamination" under the terms of the Treaty.

A number of nations have expressed interest in future missions involving humans in space that have objectives at the Moon (again) and beyond to Mars. Thus, an international consensus on planetary protection policy and implementation guidelines is essential to facilitate such missions. A set of basic assumptions has been developed by ESA and NASA regarding human mission activities and their utility, and these assumptions underlie an emerging consensus on planetary protection policy and requirements. These include, in particular, that human missions to Mars should provide for an improved capability in the search for martian habitable environments and life, and that the Earth should be protected from potential risks from returned martian materials. These assumptions have been used as a basis to develop COSPAR policy to provide a set of fundamental principles and guidelines for human missions, with an emphasis on Mars. New language to that effect was added to the COSPAR planetary protection policy, and approved by the COSPAR Bureau and Council, in July of 2008.

3. COSPAR policy on human missions

The introduction to the COSPAR policy on planetary protection recognizes that the primary goals of planetary protection, protecting the Earth and preventing forward and backward contamination, do not change when humans are involved. However, the essential association of humans with commensal microbes requires that certain variations will have to be developed in order to implement planetary protection on human missions. To mitigate the potential for danger to astronauts and to Earth, planetary protection must be considered a critical element for the success of human missions, and evaluation of planetary protection requirements should be considered in all human mission subsystems development.

Principles for human missions to Mars: The intent of this planetary protection policy is the same whether a mission to Mars is conducted robotically or with human explorers. Accordingly, planetary protection goals should not be relaxed to accommodate a human mission to Mars. Rather, they become even more directly relevant to such missions—even if specific implementation requirements must differ.

General principles include:

- Safeguarding the Earth from potential back contamination is the highest planetary protection priority in Mars exploration.
- The greater capability of human explorers can contribute to the astrobiological exploration of Mars only if human-associated contamination is controlled and understood.
- For a landed mission conducting surface operations, it will not be possible for all human-associated processes and mission operations to be conducted within entirely closed systems.
- Crewmembers exploring Mars, or their support systems, will inevitably be exposed to martian materials.

Astronaut safety is one of the highest priorities for human missions. The Space Studies Board of the US National Research Council has recommended that a set of operational constraints be implemented for human mission activities that are designed to ensure the safety of astronauts [8]. These constraints include the designation of "Safe Zones", regions that have been demonstrated to be safe for humans, and astronauts will only be allowed in areas that have been demonstrated to be safe. Initial identification of safe zones for human landing sites should be performed through direct investigation by precursor