PLANETARY PROTECTION REQUIREMENTS FOR HUMAN AND ROBOTIC MISSIONS TO MARS.

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Introduction: Ensuring the scientific integrity of Mars exploration, and protecting the Earth and the human population from potential biohazards, requires the incorporation of planetary protection into human spaceflight missions as well as robotic precursors. All missions returning samples from Mars are required to comply with stringent planetary protection requirements for this purpose, recent refinements to which are reported here.

As indicated in NASA Policy Directive NPD 8020.7G (section 5c), to ensure compliance with the Outer Space Treaty planetary protection is a mandatory component for all solar system exploration, including human missions. International planetary protection policy and guidelines for compliance with Treaty obligations are maintained by the Committee on Space Research (COSPAR) of the International Council for Science, which advises the United Nations on matters of space exploration.

The reformulation of the Mars Exploration Program must include timely and methodical approaches to develop appropriate technologies that comply with planetary protection requirements, to ensure that program architectures involving combined human and robotic missions benefit from crosscutting technologies and leveraged cost [1-3]. As indicated in several recent reports [4-7], the primary concerns for planetary protection and Mars exploration include preventing the forward contamination of Mars, documentation of astronaut health, and preventing backward contamination of the Earth. Significant investments will be needed (as supported by the NRC Decadal Survey) in technologies for health monitoring, minimization of astronaut contact with Mars dust/soil, bioburden measurements and life detection, and the containment and handling of samples returned from Mars.

Protecting Mars: Preventing the forward contamination of Mars by biological organisms from Earth is necessary to facilitate the study of life in our solar system. Experience with past robotic missions has informed the development of requirements and implementation options that are explicitly detailed in COSPAR policy and NASA Procedural Requirements document NPR 8020.12 (currently, version D). For landed hardware, compliance with these requirements involves rigorous bioburden reduction and accounting pre-launch, and operational constraints through end of mission. Hardware involved in the acquisition and storage of samples from Mars must be designed to protect Mars material from Earth contamination, and ensure appropriate cleanliness from before launch through return to Earth. Technologies needed to ensure sample cleanliness at levels similar to those maintained by the Viking project, in the context of modern spacecraft materials, are yet to be developed.

The objectives of planetary protection policy are the same for both human and robotic missions; however, the specific implementation requirements will necessarily be different. Human missions will require additional planetary protection approaches that minimize contamination released due to human exploration, including protocols on how to access locations on Mars (both characterized and uncharacterized) and performance standards for human support systems. Robotic elements of human missions must still follow relevant planetary protection requirements: access to Mars “special regions” (see NPR 8020.12D for definition) involves stringent cleanliness requirements, which will necessitate targeted technology development for both hardware cleaning and clean transfer capabilities. A conceptual approach is presented in NASA's Draft Reference Architecture 5, but implementation requirements for human-based exploration must be refined in the context of specific planned missions.

Protecting Astronauts: Article IX of the Outer Space Treaty require States Parties to take 'appropriate measures' to avoid 'adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter.' Minimizing exposure of astronauts to potentially hazardous Mars materials, as well as monitoring astronaut health and microbial populations carried by human missions, are key factors in facilitating the safe return of astronauts to Earth. Comprehensive monitoring is essential, to ensure adequate documentation in order to provide confidence that in-flight illnesses or other potential biohazards are of Earth origin. This will be required for planetary protection purposes at a level significantly greater than that needed to document astronaut health alone.

Additionally, planetary protection technology needs include the development of human habitat egress/ingress procedures that minimize contact with Martian material; medical monitoring procedures before, during and, after EVA; monitoring of the microbial inventory of human habitats; and quarantine procedures for affected astronauts. Guidelines for the human exploration of Mars, as presented in COSPAR policy, provide the framework to support requirements in these areas, however, specific implementation approaches will most usefully be developed in the context of anticipated technology developments in human health monitoring and molecular environmental microbiology.

Protecting Earth: Preventing adverse effects on the Earth's environment as a result of returning astronauts and/or samples from Mars is the highest planetary protection priority in COSPAR guidelines, in accordance with Article IX of the Outer Space Treaty. Requirements for Mars Sample Return involve stringent restrictions on release of unsterilized Mars material into the Earth environment. The European Science Foundation (ESF) has recently completed a study on assuring the safety of robotic Mars sample return missions [8] and has endorsed previous guidance that the constraints be formulated as an assurance level for the release of a particle of martian material of a size that could potentially carry biological hazards. Specific numerical requirements recommended by the ESF involve ensuring that a particle of unsterilized Mars material is contained with a probability of $1x10^{-6}$. In consideration of new information about viruses and genetic transfer agents, the particle size limit recommended by the ESF study for containment is 10nm. Containment at this level is required until samples are characterized and demonstrated to be safe for release, which includes satisfactory completion of a life detection protocol, although re-allocation of the full 'probability of release' is anticipated upon successful introduction of the return capsule into an Earth-based containment facility. Technologies for life detection, and the protocol itself, are also areas in need of additional development and technical refinement.

The Apollo Program provides a cautionary example of how NASA has implemented planetary protection on human missions in the past, for both astronaut and samples—and illustrates numerous targets for making improvements to future mission designs and procedures. The selection of appropriate spacecraft materials and hardware; the design of suitable subsystems; and the development of procedures for clean sample acquisition, handling, and containment; as well as capabilities to ensure adequate re-cleaning of sampling hardware *in situ*, are among key technology needs for human missions to Mars.

Conclusions: Planetary protection considerations for the combined human and robotic exploration of Mars will require substantial efforts in both requirements refinement and technology development. Compliance with planetary protection requirements on robotic and human Mars missions is required by both national policy and international treaty; however, specific approaches for minimizing human-associated contamination and human exposure are still to be established.

Considerable effort by both NASA and ESA has gone into identifying technologies needed for robotic Mars Sample Return, although actual development of the necessary technologies to comply with planetary protection requirements is only starting, and within NASA is on hold. Technologies developed for human Mars missions must also incorporate planetary protection constraints from their earliest development, to ensure that costs are appropriately allocated and minimize difficulty for demonstrating compliance downstream. Although minimal exposure is the goal, not all human-associated processes and mission operations can be conducted within closed systems, and astronauts will inevitably be exposed to Martian materials. Thus, studies assessing the biotoxicity of Martian dust and other materials, as well as monitoring, quarantine, and treatment technologies for affected astronauts are necessities for ensuring their return, and the safety of Earth.

Planetary protection is critical to protecting the biosphere of the Earth as well as the success of scientific investigations focusing on Mars life and habitability, and therefore is an essential element in the architecture of the Mars Exploration Program—for which the necessary preparatory activities will require significant investment.

References:

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