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PREPARING FOR THE HUMAN EXPLORATION OF MARS: HEALTH CARE AND PLANETARY PROTECTION REQUIREMENTS AND PRACTICES

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At this time there is an emerging emphasis within NASA on support for human exploration missions beyond low-Earth orbit, with the current pathway to the exploration of Mars making use of the International Space Station (ISS) as a stepping stone to a mission to a Near-Earth Object (most likely an Earth-crossing asteroid). The continuation of the ISS program to 2020 and the eventual goals of asteroid and Mars exploration highlight questions regarding astronaut health and planetary protection that have not been addressed since the Apollo program. While the short duration of the Apollo missions limited health concerns about deconditioning and bone demineralization, they provided telling lessons learned about the challenges of placing humans in contact with alien planetary surfaces. Apollo taught numerous lessons about preventing (human commensal) biological contamination of space flight hardware, planetary surfaces, and the samples collected by the astronauts, while at the same time providing an improved understanding of the effects of exposure to extraterrestrial planetary materials and environments on astronaut health. While some aspects of practice (e.g., the health stabilization program prior to space flight) are still ongoing, many of the lessons of Apollo were not learned by the current generation of space support professionals, but exist only as dusty (and only occasionally digital) records of lunar exploration. For the missions currently envisioned, it will be essential to recast and relearn the lessons of Apollo to ensure the safe return of astronauts to Earth, and indeed, the safety of the Earth biosphere, itself. This paper explores the practices and technologies that must be developed to ensure effective monitoring of astronaut health during a mission, the state of microbial populations within the closed environment of the spacecraft, as well as any detrimental health effects due either to the conditions within habitats during the mission, or from exposure to planetary (asteroidal, lunar, martian) materials. The Committee on Space Research has recently [1] cited high-level requirements for planetary protection provisions on human missions to Mars, and those will form the backdrop for discussions of the requirements for medical monitoring, microbial inventory, and contamination control required for these missions. With Mars as a potential site for extraterrestrial life and possible astronaut exposure to that life, it will be important to establish sound requirements and mission practices for that eventuality during development of the expanded human exploration portfolio.

I. INTRODUCTION

Current concepts of human Mars exploration have focused in part on long-duration (e.g., 500-day) overall missions with two long cruises separated by a limited time on the martian surface. Such missions anticipate that human explorers can be protected from radiation and provided with the capability to maintain fitness and bone density, as well as overall health, in suffice measure to allow for full capability for surface operations without an extensive period of recovery after the Earth-Mars transit.

Alternative mission scenarios, with a longer stay on the martian surface and a longer overall duration are also possible. Either way, in current mission planning there is also the expectation that a crew landing on Mars will be able to function immediately, and that recurrent extra-vehicular activity will be the principal means by which surface operations are accomplished, both with and without the assistance of robotic adjuncts. As such, humans venturing to the martian surface will have to deal with martian materials first-hand (to the extent not preventable by habitat and suit design), while human-associated contamination will also be a major consideration in system designs, and a large factor in the success or failure of the human exploration mission with respect to science capability and human safety and survival. Complexed with the long-duration medical and life support requirements of such a mission, the planetary protection concerns of forward and backward contamination (of Mars in the forward direction, and of the crew habitat and the Earth in the backward direction) will have specific relationships system-design implications and characteristics that will be complementary, and that will need to be acknowledged and included at the start of mission concept, design, and development efforts.

II. ANTICIPATED MEDICAL REQUIREMENTS

Each Mars mission scenario that has been seriously considered for humans over the last 3 decades has included a significant medical care system and varying

(mostly increasing) capabilities to deal with nutrition, radiation-related and workplace injuries, and to a limited extent, disease. At present it is anticipated that Mars-bound astronauts will be chosen from a cadre of candidates who are in good health, overall, and who will benefit from the normal array of precautions (e.g., health stabilization protocols) prior to the trip to Mars. Given that the Mars crew will be away from the Earth in a small group longer than anyone has ever been isolated from Earth, before, it can be anticipated that protection against full exposure to Earth's population upon return from Mars will also help to stabilize the health of the crew.

In preparing for the health and safety of the crew in any eventuality, a comprehensive medical care capability for a transit mission will be required to support the crew, especially in phases where there is no possibility of an immediate return to the Earth. In addition, the medical care system will have to deal with a limited, asynchronous communication capability during much of the mission [cf., 2]. Other aspects of a comprehensive medical care system related to planetary protection and with importance to human missions include:

- Contaminant transfer (human microbiome, host-microbe interactions, monitoring, quarantine, cleaning/maintenance, handling, etc.)
- EVA and mobile infrastructure & support (contamination related)- ingress/egress; sampling equipment; operations, cleaning/maintenance; monitoring, spacesuit/human microbiology etc.)
- Habitats and permanent emplacements and other natural environments (zonation, special regions, separation of living and science areas, specially managed scientific reserves? etc.)
- Materials containment & waste disposal; biological life support; food/water; sample handling; dispersal of materials beyond habitats, etc.
- Human Factors and PP (behavior; assigned crew member for PP, varied impacts of patho-physiology on operations, etc.; [cf. 3].
- Human health monitoring—spacecraft baseline and enroute, to Mars, during return flight, and after Earth return [4].

III. ANTICIPATED PLANETARY PROTECTION REQUIREMENTS

Complementing the medical system requirements are planetary protection-related requirements for a Mars mission. In 2008 in Montreal, COSPAR adopted the following general principles for planetary protection in the human exploration of Mars:

- 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 [1].

By the imposition of requirements based on such guidelines, international space agencies can together be assured of avoiding the "harmful contamination" of Mars (as specified in Article IX of the UN Space Treaty [5]), as well as "adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter" [also 5] from Mars. As seen in Table I, COSPAR has already begun to trace out associated requirements compatible with its overall guidelines for humans on Mars.

• Human missions will carry microbial populations that will vary in both kind and quantity, and it will not be practicable to specify all aspects of an allowable microbial population or potential contaminants at launch. Once any baseline conditions for launch are established and met, continued monitoring and evaluation of microbes carried by human missions will be required to address both forward and backward contamination concerns.
• A quarantine capability for both the entire crew and for individual crewmembers shall be provided during and after the mission, in case potential contact with a martian life-form occurs.
• A comprehensive planetary protection protocol for human missions should be developed that encompasses both forward and backward contamination concerns, and addresses the combined human and robotic aspects of the mission, including subsurface exploration, sample handling, and the return of the samples and crew to Earth.
• Neither robotic systems nor human activities should contaminate "Special Regions" on Mars, as defined by this COSPAR policy.
• Any uncharacterized martian site should be evaluated by robotic precursors prior to crew access. Information may be obtained by either precursor robotic missions or a robotic component on a human mission.
• Any pristine samples or sampling components from any uncharacterized sites or Special Regions on Mars should be treated according to current planetary protection category V, restricted Earth return, with the proper handling and testing protocols.

Table I: COSPAR Guidelines for Human Mars Missions [1].

IV. CONCLUSIONS

Developing a program of Mars exploration that will lead to a human mission to Mars requires a comprehensive understanding of planetary-surface conditions that may be faced by human explorers, as well as an understanding and respect for the variation from surface conditions that may be found in the martian subsurface and in other places on Mars where the crew might venture. Places on Mars where Earth-source microorganisms might survive (and which may provide a place for any potential Mars organisms to survive) are termed by COSPAR as "Special Regions" [1], and need to be avoided to prevent both inadvertent contamination of Mars as well as to avoid possible contamination of the crew. If either circumstance takes place, however, the crew should have both the medical and planetary protection related capabilities available to deal with such an exposure. Careful, coordinated, development of medical support systems and planetary protection-related capabilities will be required to ensure mission success, as well as the safety of both Mars and the Earth.

V. REFERENCES

1. COSPAR: Planetary Protection Policy (revised 24 March 2011). COSPAR, Paris, France, 2011.
2. Davis JR , Medical issues for a mission to Mars Aviat Space Environ Med. 70(2):162-8, 1999.
3. Williams RS, Davis, JR, A critical strategy: ensuring behavioral health during extended-duration space missions. *Aviat Space Environ Med* 76(6, Sec II):B1-2, 2005.
4. Rummel, J.D, M.S. Race, C.A. Conley, D.R. Liskowsky, The integration of planetary protection requirements and medical support on a mission to Mars, Journal of Cosmology 12:3834-3841, 2010.
5. United Nations, Treaty on principles governing the activities of states in the exploration and use of outer space, including the moon and other celestial bodies, U.N. Doc.A/RES/2222/(XXI) 25 Jan 1967; TIAS No. 6347, 1967.2.