ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS FOR MARS MISSIONS – ISSUES AND CONCERNS FOR PLANETARY PROTECTION.

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Introduction: Planetary protection represents an additional set of requirements that generally have not been considered by developers of technologies for Environmental Control and Life Support Systems (ECLSS). Planetary protection guidelines will affect the kind of operations, processes, and functions that can take place during future human planetary exploration missions.

Forward Contamination: Forward contamination concerns will affect release of gases and discharge of liquids and solids, including what may be left behind after planetary vehicles are abandoned upon return to Earth. A crew of four using a state of the art ECLSS could generate as much as 4.3 metric tons of gaseous, liquid and solid wastes and trash, and 2 metric tons of used hardware during a 500-day surface stay. This rate includes the fact that state-of-the-art ECLSS technology such as that currently on the International Space Station includes partial waste recycling. Certainly, further closure of ECLSS systems will be of benefit by greater reuse of consumable products and reduced generation of waste products. But how must these wastes be managed? It will be cost prohibitive to return these wastes to Earth. Process technologies to treat, sanitize, mineralize or permanently store these products will add to launch mass requirements.

It can be presumed that planetary protection will affect technology development by constraining how technologies can operate: limiting or prohibiting certain kinds of operations or processes (e.g. venting); necessitating that other kinds of operations be performed (e.g. sterilization; filtration of vent lines); prohibiting what can be brought on a mission (e.g. extremophiles); creating needs for new capabilities/technologies (e.g. containment).

Although any planned venting could include filtration to eliminate micro-organisms from inadvertently exiting the spacecraft, it may be impossible to eliminate or filter habitat structural leakage. Filtration will add pressure drops impacting size of lines and ducts, affect fan size and energy requirements, and add consumable mass. Contingency operations such as cabin depress for fire response may have to be reconsidered, necessitating additional hardware such as scrubbers for post-fire cleanup.

Technologies that may be employed to remove biomarkers and microbial contamination from liquid and solid wastes prior to storage or release may include mineralization technologies such as incineration, super critical wet oxidation and pyrolysis; however these come with significant penalties for mass, power and consumables. Additionally, operations of current and historical human spacecraft without planetary protection needs have not led to strong demand for these technologies, and their development lags behind other functions. More detailed knowledge is needed for what specific chemical and organic materials are acceptable to be vented or left behind without treatment. Are there concerns for non-biological contamination for reasons other than planetary protection, such as for protection of science?

Backward Contamination: Developers of life support systems have several concerns related to backward contamination, both physical and biological. The life support system may be an important step in minimizing the backward contamination, or have to react to that contamination happening.

The life support system is a critical part of minimizing the effects of backward contamination from dust or regolith on the Martian surface. Characterizing the properties of Martian dust before human missions is clearly important. Knowing the impacts on human health will set the limits of allowable contamination, and knowing other characteristics will help design efficient technologies for control and removal of the dust. However, it's also very important to estimate the amount of dust that will be brought into the habitat during nominal or contingency operations. Suitports and other layered defense strategies can minimize the dust or regolith brought deeper into the habitat, but it will not completely eliminate it. While it may be obvious, it's important to point out that the vehicle life support system removes dust or regolith after the crewmember has been exposed. It will not be a perfect barrier. Medical communities should be assuming some level of contact between the crewmembers and the Martian environment is inevitable.

A second backward contamination issue important to the design of the life support system is the use of in-situ resources. The essential issue is whether medical experts will allow human consumption (through drinking or atmospheric contact and metabolic use) of consumables generated from the Martian surface and atmosphere. Are there additional monitoring or measurement requirements that need to be placed on either the ECLSS or ISRU system to validate quality? There is a knowledge gap (at least within the ECLSS community) as to what contaminants will be present in ISRU generated consumables that would be different from either Earth supplied consumables or resources from recycled wastes. The contaminants will likely vary depending on process (melting ice vs. chemically reacting atmospheric components). If particular types of consumables will never be acceptable, that places an important constraint on mission and system architecture. The standards currently in place for water and air quality are typically based on describing allowable quantities for expected contaminants. The requirements and specifications used in ISS are likely not sufficient to describe the requirements for fluids and environments during exploration missions. For example, perchlorates and chromium do not appear in the Spacecraft Water Exposure Guidelines (SWEGs).

Since some backward contamination is likely inevitable, the need for quarantine is an important consideration for life support design. If a crewmember develops symptoms of illness after exposure, will the life support system have to provide an isolated atmosphere and water system to act as a medical quarantine? This essentially results in a doubling of life support functions and significant increase in vehicle size. If the quarantine is short term, simpler units may be used, but duration becomes highly important. And if waste must be disposed of after the quarantine period as if it were a biohazard, that also introduces difficult new requirements. Quarantine may also be provided by separation through the operation of distinct mission vehicles, with an attempt to minimize cross contamination when the crew transfers from the surface elements, to an ascent vehicle, to a transit habitat, and back into the Orion vehicle. The timing of these moves is based on orbital mechanics, and cannot be adjusted to wait out an illness. Thus, medical quarantine may need to be considered for all vehicle elements.

Closing Comments: Ultimately, there will be an effect on mission costs, including the mission trade space when planetary protection requirements begin to drive vehicle deisgn in a concrete way. Planetary protection requirements need to be considered early in technology development and mission programs in order to estimate these impacts and push back on requirements or find efficient ways to perform necessary functions. It is expected that planetary protection will be a significant factor during technology selection and system architecture design for future missions.

References:

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