BIOLOGICAL POTENTIAL OF AEOLIAN AND SUBSURFACE MATERIAL AT JEZERO.

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Introduction: The planned Mars Sample Return (MSR) campaign faces significant challenges related to the handling and return of Martian samples, particularly due to the planet's pervasive dust. Before human exploration of Mars, crucial information could be obtained by analyzing returned samples to assess the biological potential of Martian dust. Such an assessment would help evaluate potentially significant impacts on forward planetary protection, science goals, and backward planetary protection.

The two distinct categories of materials to manage are: 1) Martian aeolian material (e.g., wind-borne dust) and 2) subsurface Martian material exposed through exploration or the sample acquisition process, such as the approximately 10 cm depth targeted by the Mars 2020 Perseverance mission. The Martian atmosphere continuously redistributes and deposits particulates on spacecraft and sample containers, necessitating operational and hardware strategies to effectively mitigate particle accumulation, ensuring redundant containment of the acquired samples.

Current microbial abundance estimates: Sterilization is often referenced as a significant potential mitigation for Mars particle contamination. Typically, sterilization requires an understanding of the number of initial quantity of contaminants to be treated. The MSR program has estimated that there are approximately 20 billion particles per gram of aeolian Martian material. In contrast, to assess risk for JAXA's MMX (Martian Moons eXploration) sample return mission, the 2019 NASEM/ESF report assumed an estimate of 100,000 cells per gram of Martian material [1]. Even with such a conservatively high estimate, ≤1 in 200,000 Mars particles would be considered biological, the report found. Thus, the sterilization challenge presented by Mars dust should be carefully considered with respect to the maximum biology potentially present.

Dust Management Initial Conditions: The December 2023 baseline architecture of the MSR program implemented tremendous efforts to minimize particle accumulation to ≤40 mg, equivalent in mass to 40 grains of table salt. Current dust management approaches include aseptic transfer of surface-exposed hardware into nested containers or exterior sterilization followed by encapsulation. For now, effective sterilization or aseptic transfer remains crucial for planetary protection, but these measures may be refined in scope prior to human missions to Mars based on the results of MSR. Therefore, it is important to ensure that appropriately conservative estimates of potential biology inform future containment and mitigation measures.

Microbial abundance refinement: Evaluating cell-abundance estimates and their impact on planetary protection measures could help refine risk assessments and optimize planetary protection strategies for Mars missions. Data provided by the examination of potential returned samples from Jezero Crater could lead to policy revisions for future robotic and crewed planetary missions. In particular, recent data from Jezero Crater [2], where the Perseverance rover landed, indicates a lack of habitable "special regions," with habitable temperatures and liquid water not co-occurring in the near-surface environment. This, combined with the high surface radiation environment [3], suggests that the biological potential of Jezero's aeolian material may be lower than the global Mars average.

This issue of biological potential of mars materials, both aeolian and material exposed during exploration can also be approached by considering the potential metabolic atmospheric energy sources available to support microbiota on Mars. Sholes et al. (2019) estimated the maximum biomass in the top kilometer of Mars at 1,000 cells per gram. This represents a robust maximum for actively metabolizing microbial biomass on Mars and represents power limits for only repairing cellular molecules without cellular growth, motility, nor reproduction. Known metabolic inefficiencies would likely reduce the amount of potential organisms by an order-of-magnitude [4].

Conclusions: Refined estimates of the biological potential of Martian material could significantly and positively impact early architectural choices, costs, and schedules for future missions to Mars. Additional research and insights informed by current data (e.g., the Curiosity and Perseverance missions, and eventually MSR) can better inform human exploration of the Red Planet. The refinements may in turn drive down costs to sample return and human exploration, thus making Mars missions more widely accessible.

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