Biological In-Situ Resource Utilization (BISRU) for Mars – merging planetary science, space biology, microbial ecology, agricultural sciences, and more.

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Introduction: Biological in-situ resource utilization (BISRU) uses Earth biological mechanisms to extract, alter, or use non-Earth materials to support human habitation and closed-loop life support systems. BISRU practices are ideal for bioregenerative life support systems on Mars [1-4], being light-weight, cost-effective, and self-replicating. Resupply missions from Earth to Mars will likely be years apart, and establishing biology-based alternatives to processes that require complex electronic equipment will be vital to the long-term success and stability of any future Martian settlement. This is in line with a key recommendation from the 2011 National Research Council Decadal Survey on Biological & Physical Sciences in Space, bolstered by the 2018 Midterm Assessment of the 2011 Decadal Survey, which states that "NASA should develop a research program aimed at demonstrating the roles of microbial-plant systems in long-term life support systems".

However, the related methods and technology for BISRU are only beginning to be developed, and government, academic, and industrial research into this arena does not yet share a cohesive vision or set of goals. Expertise from various fields such as plant biology, microbial ecology, molecular biology, engineering, and planetary science will be required to develop and implement BISRU successfully in the space environment, but researchers in many of those fields still need to consider their work relevant to BISRU. For example, Mars planetary scientists engaged in characterizing the minerology and physical properties of the Martian surface are vital to understanding the toxicity and potential for use of these materials to support human settlements, as well as mapping locations of key resources.

Biological In-Situ Resource Collaborative (BISRU-C): There are common knowledge & communication gaps in implementing BISRU for food production, biomanufacturing, bioremediation, biomining, etc. Interdisciplinary communication and partnership will be necessary to develop & implement BISRU science and technologies and support the most recent NASA BPS decadal survey science objectives. The Biological In-Situ Resource Collaborative (recently founded by researchers at WSSU, Florida Tech, LPI, Blue Marble, and JPL) seeks to do the following:

1. Bring together interdisciplinary researchers from multiple fields (space biology, planetary science & astrobiology, ISRU, life sciences, geoscience, etc.) involved and/or interested in BISRU science & technology development to foster communication and collaboration, 2. Assess the state of the art of BISRU research to update our collective understanding of this growing field, 3. Work as a community to identify science and technology gaps, new directions for research, and unaddressed questions in the field of BISRU to guide researchers, mission planners, and funding agencies to fully address the challenges of human habitation of space. 4. Drive advancement of BISRU science & technology by fostering partnerships across academia, government, and industry.

Plant Trek - BISRU Research In Action: The Plant Trek project addresses the challenge of developing agriculturally stable and usable soil from mars regolith simulants, in order to enable plant growth, sustain plant-microbiome interactions, minimize plant stress, and optimize food production and life support by using approaches based on primary succession in Earth ecosystems. Plant Trek evaluates bioremediation of toxic elements in regolith such as perchlorate by identifying and testing critical microbial consortia involved in relevant metabolic pathways and evaluating microbial community evolution, nutrient availability, and soil structure development. Understanding these metrics can both reduce human health risks and optimize carbon and nitrogen content, nutrient availability, and soil structure, improving drainage and facilitating plant growth. The goal of Plant Trek is to provide an integrated process pathway for soil formation using in situ resources (regolith), thus facilitating the development of sustainable agricultural substrates on Mars.

Figure 1: Microbially-induced sediment structure in a naturally perchlorate-reducing community, Fig 2D from Lynch et al. 2019 [5] - an example of a microbial consortium being tested by Plant Trek for perchlorate bioremediation

References:

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