Integration of lessons from recent research for "Earth to Mars" life support systems

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Abstract

Development of reliable and robust strategies for long-term life support for planetary exploration needs to be built on real-time experimentation to verify and improve system components. Also critical is the incorporation of a range of viable options to handle potential short-term life system imbalances. This paper revisits some of the conceptual framework for a Mars base prototype previously advanced ("Mars on Earth") in the light of three years of experimentation by the authors in the Laboratory Biosphere, further investigation of system alternatives and the advent of other innovative engineering and agri-ecosystem approaches. Several experiments with candidate space agriculture crops have demonstrated the higher productivity possible with elevated light levels and improved environmental controls. For example, crops of sweet potatoes exceeded original Mars base prototype projections by 83%, ultra-dwarf (Apogee) wheat by 27%, pinto bean by 240%, and cowpeas slightly exceeded anticipated dry bean yield. These production levels, although they may be increased with further optimization of lighting regimes, environmental parameters, crop density etc. offer evidence that a soil-based system can be as productive as the hydroponic systems which have dominated space life support scenarios and research. Soil also offers several distinct advantages: the capability to be created using in-situ space resources, reducing reliance on consumables and imported resources, and more easily recycling and incorporating crew and crop waste products. In addition, soil itself is a complex microbial ecosystems which help prevent the buildup of trace gases or compounds, and thus assist with air and water purification. The atmospheric dynamics of these crops were studied in the Laboratory, adding to the database necessary for managing the mixed stands of crops essential for supplying a nutritionally adequate diet in space. The paper will explore some of the challenges of small bioregenerative life support: air-sealing and facility architecture/design, balance of short-term excess of carbon dioxide and oxygen through staggered plantings, options for additional atmospheric buffers and sinks, lighting/energy efficiency engineering, crop and waste product recycling approaches, and human factor considerations in the design and operation of a Mars Base. "Earth to Mars", forging the ability to live sustainably in space

(as on Earth) will require continued research and testing of these components and integrated subsystems; and the development of a step-by-step learning process.