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DEVELOPMENT OF A SIX-FLUID ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM MODEL FOR HUMAN SPACEFLIGHT APPLICATIONS

Abstract

This work details the development of a six-fluid environmental control and life support system (ECLSS) model for human spaceflight applications. The effort adopts a systems engineering approach to the development of a mathematical model underpinning the design of successful ECLSS systems and outlines strategic synergies with other spacecraft systems. The model details the mass, species and energy balances associated with six key fluids of interest for long-duration, highly closed ECLSS systems including oxygen, nitrogen, carbon dioxide, water, hydrogen and methane as an energy carrier. The model further incorporates a variable degree of biomass production to supplement caloric requirements of crew members. The model admits varying degrees of in-situ resource utilization to supplement critical fluids, variable leakage rates and degrees of closure within each fluid loop, can accommodate a number of fluid processing technologies and technology improvements, and provides requisite implied energy requirements to accommodate these conditions.

Several ECLSS models are developed and discussed for targets of interest for long-duration human exploration missions, including the moon, Mars and Saturn's moon, Titan. Available in-situ resources for each of these targets, and the energy penalties associated with their incorporation into ECLSS fluid cycles can be derived. This provides some critical insights informing design of these future systems.

Finally, provisions to include six additional macro-mineral cycles into the framework of the six-fluid model are discussed. These will be critical to the development of a successful biomass production capability essential for long-term ECLSS plants. The macro-minerals of interest are calcium, sodium, chlorine, magnesium, potassium and phosphorus. Inclusion of these compounds in a biomass-producing closed ECLSS system represent a second-order refinement on the six-fluid model, and will provide engineers and mission designers with essential mission-planning data essential for resupply, supplementation or additional in-situ resource production requirements.