Quantifying ECLSS Robustness for Deep Space Exploration

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Human exploration of deep space will require Environmental Control and Life Support Systems of increasing robustness as mission duration and distance from Earth increase. As crews travel to distant unexplored environments, designers will need heightened confidence in life support availability under increasing levels of uncertainty and risk. Variation in system performance, environmental conditions, resource consumption, waste generation, and even mission characteristics will lead to unexpected responses, increased likelihood of failures, and even design obsolescence. The cost of system failures will also rise, due to launch mass and volume constraints, time and cost of resupply, and reduced ability to abort to Earth. If not accounted for early in design, the increased risk and cost of uncertainty might preclude human deep space exploration. ECLSS robustness is "the ability to maintain habitable conditions for crew survival and productivity over the mission lifetime under a wide range of conditions." This wide range of conditions includes ordinary usage, temporary environmental disturbances or disruptions (both foreseen and unforeseen), and sustained changes in the system or mission context. ECLSS robustness must be quantifiable for design evaluation, comparison, improvement, and optimization. A robustness metric should address spacecraft habitability, not just crew survival; apply to all levels of system abstraction (component level to system level); apply to all design phases or levels of fidelity (conceptual through detailed design); be practical for use, relevant, and objective; and be compatible with existing assessment tools and all technology types. This presentation reviews robust design methodology and proposes a metric to quantify ECLSS robustness, for use in design evaluation and improvement.

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Christine is co-founder and Vice President of Space Lab Technologies, LLC. Her multi-disciplinary education spans systems engineering, bioastronautics, and life sciences, providing her with a unique combination of skills for space crop production technology development. She is currently a PhD student at the University of Colorado Boulder, studying the optimization of environmental conditions for duckweed yield and nutritional quality in space applications. Before coming to the University of Colorado, she was a Systems Engineer and Mission Manager for the NASA Sounding Rocket Operations Contract (NSROC). She co-founded Space Lab Technologies, LLC in 2016, with the mission of advancing technology for human exploration of deep space. At Space Lab, her responsibilities include project management, business development, systems engineering, integration and testing support, data analysis, technical writing, and research for all projects. She is also Principal Investigator for Space Lab's *μG-LilyPond*™ project, a floating plant cultivation system for microgravity, under NASA STTR Phase II contract.