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COMMONALITY ANALYSIS FOR EXPLORATION LIFE SUPPORT SYSTEMS

Abstract

Human exploration of the Moon and Mars, as well as other potential deep space targets, will require the development of a number of new space systems. Some of these systems are already under development, such as the Crew Exploration Vehicle (CEV) or the Ares launch vehicles; others are in the planning stages, such as the lunar lander and lunar surface infrastructure. The sustained development and operation of these new systems requires significant resource expenditure and introduces significant developmental and operational risk; commonality in design, technologies, and operations offers the potential to improve the life-cycle development cost and risk properties. Specifically, commonality can (1) reduce overall development cost and risk through the intentional or unintentional reuse of designs from heritage systems, (2) reduce operational risk through increased operational experience with fewer custom designs, and (3) reduce operational cost through the maintenance of fewer dedicated production lines as well as benefitting from learning curve effects and economies of scale. The downsides of commonality include potentially increased up-front cost and risk due to the additional requirements that common designs must satisfy.

This paper investigates opportunities for commonality in exploration life support systems. Specifically, five different life support use cases are considered: life support in (1) a suit for use in-space and on planetary surfaces, (2) the lunar lander, (3) a habitat for the lunar surface or Earth-Mars transit, (4) a pressurized rover, and (5) a Mars surface habitat. For each of these use cases a quantitative analysis of architectural options is carried out and a set of interesting architectures is selected. Based on these interesting architectures for each of the systems a set of interesting portfolios of system architectures is enumerated. Within the different portfolios a systematic analysis of opportunities for design and technology commonality is carried out using a semi-automated tool. An assessment of the benefits and penalties of specific commonality opportunities is carried out, and a set of recommendations for interesting commonality opportunities and associated design implementations is derived.

The results of the analysis indicate that the above portfolio of use cases will very likely require the development of water regeneration, regenerative CO2 removal, and CO2 regeneration technologies. Specific opportunities for commonality include the use of a common regenerative CO2 removal system across all use cases, and the provision of water and CO2 regeneration systems for low-gravity use that are common for lunar and Mars applications.