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STUDYING THE COMPLEX BEHAVIOR OF HYBRID LIFE SUPPORT SYSTEMS WITH SYSTEM DYNAMICS

Abstract

Humanity's plans to further explore space require the development of bio-regenerative life support systems fully incorporated into habitats. Nevertheless, within the foreseeable future, it is unfeasible to completely replace physico-chemical life support technologies by biological processes. Hybrid systems containing both types of systems are more realistic. Bio-regenerative processes will be complemented with a physico-chemical backup for redundancy reasons, and vice versa. Hybrid life support systems can also be seen as manmade closed ecosystems, which differ from their prototype biosphere (Earth), especially in the size. Sustainability of the biosphere is ensured by its biological diversity that creates an intricate network of metabolic paths with fail-safe redundant functions, by buffer stocks of inert biomass, and by the huge size of the planet and atmosphere itself. Such a system, produced by evolution is sustainable by stochastic control. In contrast, in a small manmade closed ecosystem, such as a planetary habitat, all these factors become ineffective. In such a system, diversity and size are not sufficient for stochastic mechanisms to operate successfully. Manmade closed ecosystems require non-stochastic control and modelling to compensate the lack of buffer capacity for dampening the effects of periodic events and failures. System dynamics is a methodology to study the dynamic behavior of complex systems and how such systems can be defended against, or made to benefit from, the shocks that fall upon them. Applying system dynamics modelling for studying life support systems is a promising approach. It can lead to new insights into the complex behavior of closed ecosystems, such as future crewed planetary habitats. Better understanding of the overall system behavior also helps to develop sustainable, reliable and resilient life support architectures for future human space exploration.