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# MODELING AND SIMULATING A REGENERATIVE LIFE SUPPORT SYSTEM TO UNDERSTAND THE EFFECTS OF SYSTEM INTERACTION ON SURVIVABILITY DURING DEEP SPACE MISSIONS: AN AGENT-BASED APPROACH

**Abstract**

To enable sustainable long-duration human space flight, regenerative life support systems (RLSS) will be indispensable. Waste materials will need to be processed and transformed back into nutrients for life-supporting ecosystems. MELiSSA (Micro-Ecological Life Support System Alternative) is a well-documented and studied example of such an RLSS, developed by the European Space Agency. The system consists of five interconnected compartments: a crew compartment, an edible plant/algae compartment, and three types of bioreactors. The microorganisms in the bioreactors gradually break down the waste materials of the astronauts and provide the edible plants and algae with their necessary resources. This paper proposes a model of an agent-based system (ABM) of MELiSSA in which the five compartments and their interactions are modeled and implemented using virtual agents that represent humans, plant plots, and bioreactors. The model also includes the corresponding mass flows of chemicals. For each type of agent, its properties, behavior, life cycle, and rules of interaction are described. An 'administrator agent' implements 'top-down' rules for overall control where needed. The behavior of each biological agent is modeled according to the expected behavior and main chemical reactions within each MELiSSA compartment, as documented in publicly available sources. Rules implemented to describe the complete life cycle of the agents – e.g., growth curves and susceptibility to nourishment deficits – are also included. This 'bottom-up' approach, characteristic for ABM, allows for the emergence of patterns that provide insight into the behavior of the overall system. In addition, the mass flows are made visible as the different chemical compounds are exchanged between compartments. This agent-based system of MELiSSA is, in fact, a simulation platform with which the behavior of the cycle as a whole, down to its individual agents, enables exploration of the robustness of the system and the impact of stressors on survivability. A series of simulation experiments has been set up to this purpose. Two types of stressors are used in these experiments. First, stochastic outputs from at least one of the compartments, beginning with the crew compartment. Second, environmental stressors, more specifically cosmic radiation causing loss of metabolic functionality and particle impact causing catastrophic failure of parts of the life support system. This research is part of the E|A|S (Evolving Asteroid Starships) project by the DSTART team at Delft University of Technology. The project entails conceptual research on interstellar travel, including onboard regenerative ecosystems.