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Strategies for Rapid Implementation of Interstellar Missions: Precursors and Beyond (4)

Author: Dr. Angelo C.J. Vermeulen
Delft University of Technology (TU Delft), The Netherlands

Ms. Arpi Derm
Blue Origin LLC, United States
Mr. Alvaro Papic
Chile
Mr. Farshad Goldoust
The Netherlands
Prof. Igor Nikolic
Delft University of Technology (TU Delft), The Netherlands
Prof. Frances Brazier
Delft University of Technology (TU Delft), The Netherlands

INTERSTELLAR SYSTEMS AT THE EDGE OF CHAOS

Abstract

Human interstellar exploration involves navigating through a realm of significant uncertainty. Assessing the exact impact and consequences of moving at high velocities through the interstellar medium is challenging. Interstellar space is home to considerable amounts of cosmic dust, comprising microscopic particles with a wide range of sizes and compositions. At high speeds, spacecraft face significant risks from accumulating collisions with these particles. However, the expansive nature of interstellar space currently makes it impossible to accurately measure and chart the spread of this dust along specific trajectories. Interstellar space is also filled with high-energy cosmic rays, emitted by distant stars and other cosmic bodies. Dominated by protons and atomic nuclei, these cosmic rays travel nearly at the speed of light. The enduring effects of exposure to such radiation on the spacecraft, its crew, and the life support systems that sustain them remain unknown.

The question then arises how to design an interstellar spacecraft capable of withstanding such inherent uncertainties. The solution requires a system robust enough to remain functional across diverse conditions. To try to cover for all possibilities in a top-down approach quickly becomes unfeasible. A promising direction is a bio-inspired adaptative approach. The Evolving Asteroid Starships (E|A|S) project integrates the utilization and recycling of local resources, self-organization, and bioregenerative principles to create a resilient spacecraft design. This aligns with the top priorities from NASEM's 2023 decadal survey, emphasizing space research on circular materials and bioregenerative life support. Within the framework of the E|A|S project, two distinct computer models have been developed, aiming for their eventual integration into a unified multi-model system. The inspiration for these models came in part from ESA's MELiSSA program and a visionary 1982 NASA study on a self-replicating lunar factory.

Once living artificial ecosystems and self-organizing architectures are deployed, one is confronted with potential chaotic behavior characteristic of complex systems. Sets of critical conditions that can push an otherwise stable self-sustaining system into collapse and failure were identified. It's crucial to gain a deeper understanding of how these systems function over extended periods, both under ideal environmental conditions and within the unpredictable exacting context of the interstellar medium. To address these challenges, the key drivers of systemic resilience (or lack thereof) were identified through an exploration of the characteristics of the individual components of each system. Moreover, potential mitigation strategies

were also explored. These include enlarging buffer capacities, integrating redundancy, and enhancing system adaptability.