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Author: Ms. Olivia Borgue
Initiative for Interstellar Studies, United Kingdom, olivia.borgue@gmail.com

Dr. Massimo Panarotto
Chalmers University of Technology, Sweden, massimo.panarotto@chalmers.se

AN ECONOMIC ANALYSIS OF NEAR-TERM SELF-REPLICATING PROBES FOR SPACE EXPLORATION

Abstract

Self-replicating probes are spacecraft with the capacity to create copies of themselves, as they harvest material from celestial bodies. Self-replication would potentially allow for an exponential increase in the number of probes and a reduction in the number of launches, and thereby drastically improve the efficiency of space exploration. Despite this potential, is still unclear how far they are feasible. In a previous paper, we proposed a concept for a light weight, less than 100kg, partially self-replicating probe based on current and near-term technologies. Partial self-replication means that replication cannot be sustained indefinitely, as some components, such as microchips and other microelectronic components, will not be replicated but brought on board from Earth.

The purpose of a partially self-replicating probe is to trace a path towards self-replication with near-term benefits, rather than attempting full self-replication. However, partial self-replication does not have the same economic benefits than full self-replication. Replication cycles are constrained by the non-replicable material on board, and launch costs increase as the payload weight increases.

In this study, a monetary value model is implemented to analyze the economic feasibility and benefits of partially self-replicating probes. In this economic analysis, design parameters (such as weight or percentage of self-replicating components), and mission parameters (such as transfer time or resource gathering time), are varied, combined, and analyzed through Monte Carlo simulations.

As a result, we propose a selection of economically feasible partially self-replicating probes alternatives for space exploration. Moreover, we identified the technology gaps that are the most profitable to address. We conclude that small-scale, near-term partially self-replicating probes are economically feasible and beneficial for space exploration.