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EVALUATING THE SUSTAINABILITY OF LONG TERM MANNED MARS CAMPAIGNS USING A PHYSICAL ECONOMICS FRAMEWORK

Abstract

Methods for evaluating sustained manned Mars campaigns for their long-term sustainability include a space logistics framework developed at MIT. Most evaluations performed to date assume that habitats and all essential equipment are manufactured on Earth and transported to Mars, where they can be optionally partially repaired from imported feedstock or in-situ resources.

Building on this work, this paper relaxes the above assumption and looks further out on the time horizon to consider long-term, Mars-centric manufacturing and construction technology development paths, for habitats and all systems including ECLSS, that might inform different early manifesting decisions.

With the earliest possible emergence of self-sustaining organic growth on Mars as the goal, we evaluate alternative long-term campaign architectures against this goal by adopting a physical economics framework and considering dynamic interactions among five aggregated, interdependent variables embodied into a systems dynamics model:

- Habitable pressurized volume **V**
- Manufacturing equipment **M**
- All other durable equipment **K**
- Energy production capacity **E**
- Consumables production capacity**C**
- Number of persons supported **L**

To inform the analysis, suitable physicoeconomic performance metrics are used to trade alternative campaign manifesting strategies and also to quantify the long-term benefit of new campaign architectures relative to familiar baselines. In particular, by allowing for **V** and **K** to be increasingly manufactured in-situ on Mars over the long term, we demonstrate that alternative early manifests with lower **V**, **L**, **K** and **C** and higher **M** and **E** can bring forward the emergence of organic growth through long-term and partly self-reinforcing increases in **V**, **C**, **K**, **M** and **E**. This conclusion informs present-day deliberations on manifesting strategies for the early flights of long-term Mars campaigns and assists in prioritizing Martian manufacturing and construction technologies for TRL development. Further detailed work focusing on the delta NPV of specific technologies and using the same analytical framework would usefully validate the conclusion for these technologies and strengthen the case for their development and early adoption.