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THE CIS-LUNAR ECOSYSTEM - A SYSTEMS MODEL AND SCENARIOS OF THE RESOURCE INDUSTRY AND ITS IMPACT

Abstract

Several private companies have been planning to establish new business ecosystems in space, the most famous being SpaceX's Mars colonization plan. The task of this study is to model future ecosystems in cis-Lunar space, for a leading small space company, using a recently-developed multi-methodology based on System Dynamics and scenario planning. Establishing a novel ecosystem is challenging, requiring profound understanding of societal dynamics. The client's goal is to help create the ecosystem, by promoting stakeholder engagement with a logical vision, and understanding the key levers to creating it. The ecosystem is a space resources industry focused on Lunar water. The scope includes both economic and engineering facets, and the objective is "*To articulate a credible, feasible $40B cis-Lunar economy: 'vision 2040'*".

System Dynamics (SD) modelling is common in business & policy planning, popularized by *The Limits to Growth*. It visually shows a problem's "dynamic structure", and models both social, soft variables and technical, hard ones. Formal scenario planning grew out of WW2 planning, and was adopted by Shell, then better-prepared for the 1970s oil shocks. Scenarios are imaginative "histories of the future", intended to articulate plausible futures and isolate key decisions. SD and scenario planning have complementarities, and are deployed together here.

We first narrow down candidate markets to GEO telecom and exploration markets, focusing on the supply side. Scenario planning ranks *Quantity & accessibility of resource finds* as the most critical uncertainty, followed by *Priorities of government expenditure on resource exploration*. SD modelling was influenced by oil industry models. The matured model is primarily four interacting systems: a resources *exploration system*, a *production system* focused on resources sales, an *R&D system* increasing the level of exploration technology, and a *demand system* (with underlying *satellite industry*). There are also a *natural (resources) system*, and *government system* - a source of exogenous interventions.

The SD model helps articulate 2 distinct scenarios in detail (from 4 key identified). *Moonopolis* is characterized by plentiful resource finds, strong government support for production, and a significant private on-orbit refuelling market. *Apollo 2.0* is a low-resources scenario, but with robust government support. Sensitivity analysis of 20-year ecosystem size reveals the top third of 25 variables each impact by a factor of 2+. Sensitivity is dominated by production system uncertainties. The structure of the problem seems to be a series of growth bottlenecks, starting with production. Ecosystem sizes of $20B/year by 2040 are achievable in favourable conditions.