

## **Expanding the Sphere of Commerce Beyond the Earth: First Steps Toward Creating Space-Based Business Ecosystems**

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### **Abstract**

The goal of this paper is to bring the latest thinking about business ecosystems and system dynamics modeling to bear on the critical problem of determining which financial levers will most effectively drive large-scale commercial activity in space. While building economic models around discrete activities such as mineral extraction from near-earth asteroids is a critical step toward developing a commercial roadmap, we believe that a more fundamental step is envisioning the potential business ecosystems – the comprehensive web of activities and financial flows surrounding a commercial activity – that would enable and drive large-scale space-based commerce. What forms of space-based business ecosystems can we envision and what enablers are required to bring them into being?

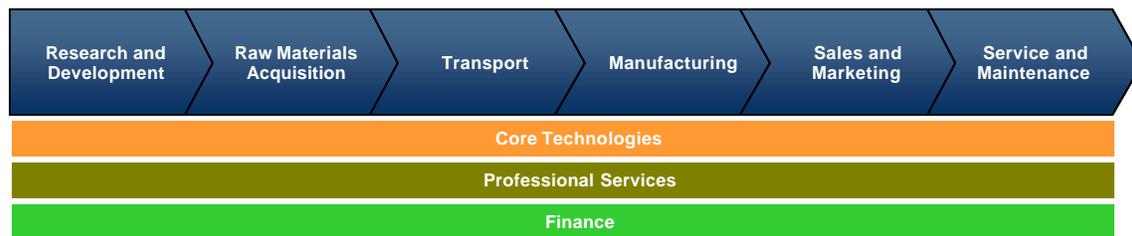
As we explore possible scenarios for the development of large-scale space-based commerce, the broad challenge is to understand the commercial context within which these activities must take place. For example, who will provide the markets for resources extracted from asteroids or planetary surfaces? What transport infrastructure will deliver extraction equipment to, say, a near-earth asteroid and haul extracted materials to a customer? What is the first step towards creating a web of support activities required to ultimately create a viable business ecosystem around some core commercial activity? Is successful development dependent upon multiple activities occurring simultaneously, or can it be bootstrapped through some sequence of intermediate activities?

Business ecosystems evolve as a web of economic activities focused on delivering a high-value product or service to a defined customer segment. A number of concepts for space-based products or services have been suggested over the past several decades as potential drivers for the creation of space-based commercial ecosystems. Perhaps the most elaborate and vividly articulated of these is Gerard O'Neill's vision of a complex business ecosystem encompassing lunar mining and space colonies built to support the construction and operation of vast solar-power satellites that supply clean, inexpensive energy to earth. Robert Zubrin has envisioned a form of "triangular trade" among the Earth, Mars, and the asteroid belt as a means of supporting Martian settlement and unlocking the mineral resources of the asteroid belt. Zubrin's vision is essentially a colonial business ecosystem of real estate development and commerce in raw materials. Mark Sontner has speculated about a market for volatiles extracted from asteroids to provide fuel for a wide range of orbital activities associated with satellite

communications and space tourism. Looking farther into the future, others have envisioned a model based on extraction and trade in Helium-3 from lunar regolith or the atmosphere of Neptune in support of a fusion-energy-powered economy. Near-term models have focused on space tourism or even support for government-funded research and exploration as central activities around which to build initial business ecosystems.

The commercial challenges to creating such business ecosystems are daunting. Even a rudimentary value chain for a product-centric space-based business ecosystem contains numerous components (Figure 1).

Figure 1. High-Level Value Chain Activities for Space-Based Commerce



Where are we to start as we seek to develop such an ecosystem? Which first steps are most likely to lead to the development of a large, sustainable business ecosystem? In addition, space-based activities have relied heavily on government funding. It has been and continues to be difficult to conceive of scenarios for the development of new space-based business ecosystems that do not depend upon significant government involvement. How can this government role be structured to most cost-effectively enable the creation of self-sustaining business ecosystems?

Furthermore, as we examine the history of terrestrial business ecosystems, such as the petroleum industry, are there fundamental principles that we can identify or analogies we may draw that can show us how to practically begin to build the business ecosystem that must emerge to support the level and intensity of economic activity required to expand the sphere of commercial activity beyond the Earth? Does the limited development to date result from a lack of technology, business models, or vision? The technical challenges are real but perhaps the easiest roadblocks to surmount. The business model challenges are far greater. Expanding the sphere of commerce beyond Earth will require significant investments in numerous areas that have largely gone unexamined to date. Perhaps most significant, neither key requirements nor the implications of successful development are even on the radar screens of most business strategists today.

In this paper, we take an innovative approach to addressing many of these issues. First, we explore the key components required for the development of successful space-based business ecosystems and the likely drivers and players in the development of each component. Second, we build a set of maps of potential space-based business ecosystems and preliminary system dynamics models. Finally, using these maps and models we explore and evaluate several scenarios for initiating large-scale commercial space activity.