

EVOLUTION OF GOVERNMENT AND INDUSTRIAL PARTNERSHIPS TO OPEN THE SPACE FRONTIER

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ABSTRACT

If the logical extension of the current exploration program is to develop self-sustaining settlements on the Moon and Mars over the next few centuries, then there is a path that takes civilization from its current one planet existence to a multi-world future. By considering the far-term goal of space settlements as a desired endpoint and using the current state as a starting point, the policy drivers and potential pathways to the goal of sustainable space settlements can be explored.

This paper describes a three-phased evolution of government and industrial partnerships from current day relationships to a time when there are sustainable settlements in space. Phase I details the current state government-led exploration while Phase III describes a desired endpoint of self-sufficient settlements in space. Phase II is an important transition phase, which acts as a bridge between now and the future. This paper discusses the critical evolution that must take place in two key areas to ensure a thriving future in space; space transportation and the right to use space property and resources. This paper focuses on the enabling role of government necessary to achieve United States (U.S.) goals for space exploration and open the frontier.

INTRODUCTION

Since the U.S. formally announced its intentions to go back to the Moon, Mars, and beyond in 2004, many of the world's leading space agencies have also started on similar courses toward sustained exploration and development of space. These government-sponsored space agencies have evolved powerful symbiotic relationships with their national aerospace industries. These relationships have developed over the years and produced successful national

and cooperative international space programs primarily focused on the development of single spacecraft missions for specific scientific or applied objectives with the notable exception of the International Space Station (ISS).

Looking at the U.S., the strategic goals of the civil space program have changed dramatically since the 'Vision for Space Exploration' (VSE) (Bush, 2004) was established. Over the last decade most of human space flight missions were focused on construction and operation of the ISS, which is a destination in its own

right and originally without a clear role within the larger exploration context. In fact, until the VSE there was no larger exploration context for the ISS. Currently, within the VSE most NASA missions are part of a larger strategy of human and robotic missions building on each other in a stepping stone fashion to enable robots and then humans to travel to the Moon, Mars, and beyond with the logical outcome of someday creating a sustainable presence in the Solar System. The VSE's far ranging goals demand a reassessment of traditional approaches toward exploration and a reexamination of the relationship between government and industry.

To provide a framework for the discussion, the future state of sustained space settlements will be briefly defined along with a summary of the current state of government-led exploration. Then a description of the strategies and tactics necessary to build an evolutionary pathway connecting the two eras will explore potential policy implications necessary to reach the state of sustainable settlements. Specifically, the discussion will focus on the important relationship between U.S. aerospace industry and the government-led space program in areas of space transportation and the rights to use space resources. It is important to explore how these parameters might evolve to create sustainable exploration. The major outcome of this process will be to identify how the role of government will need to change over time to fulfill the long-term potential of the VSE. Current commercialization opportunities such as the Commercial Orbital Transportation Services (COTS) and the NASA-Google relationship are excellent examples of innovation in government and industrial

partnership, which can have a profound impact on opening the frontier of space.

A VISION OF THE FUTURE

One potential future state is described below to set the appropriate context to explore government-industrial partnerships.

Sustained human presence on the Moon and Mars

Mars: In 100 to 150 years there are sustainable settlements on Mars. The human population on Mars has reached a critical mass so that it is no longer dependent on Earth for supplies. The Martian settlement produces enough food and power to keep the settlers healthy and comfortable. Although there is not as much variety of food and products as on Earth, each year the growing population successfully introduces new goods into their domestic market as they continue to expand the settlements and terra-form the harsh environment of Mars. Space transport ships from Earth routinely arrive biennially on the 26-month cycle that favors transportation between Earth and Mars. The Martian economy is strong and Martian goods are traded for Earth-developed goods. On Earth, Martian goods are considered exotic luxuries for high-end consumers developed in the low gravity and the thin atmosphere of Mars. In addition, there is a thriving tourist and service industry during the right times of the Earth-Mars cycle.

Moon: The Moon has multiple permanent self-sufficient outposts. They began as multi-national and single nation bases or stations but have evolved into independent outposts over the years. A thriving industry has developed to

support a strong cis-lunar economy focused in areas like space tourism, supplying oxygen and fuel to geostationary platforms, solar power beamed to cis-lunar spacecraft and industrial production of new materials that take advantage of the low gravity and vacuum on the Moon. Spaceships arrive and depart almost daily bringing supplies and leaving with Lunar goods and resources for Earth orbiting satellites and markets on Earth. The population of the Lunar outposts is mostly transient because of the long-term effects of low gravity and radiation on the human body. Much of the work conducted on the Moon is automated and accomplished by robots.

This description of one potential future in space is based on a logical extension of the human history of exploration and expansion. It favors the belief that humans will leave Earth to establish new beachheads of civilization throughout the universe beginning with our nearest neighbor, the Moon, and then on to Mars. It is one of many likely scenarios and includes the following assumptions; 1). The settlements on Mars and the outposts on the Moon have evolved to where they are not solely supported by governments on Earth, 2). The Martian settlements are self-sufficient and are no longer dependent on supplies from Earth to exist, and 3). On Mars, people make their home in the settlements and raise families there.

By envisioning this future state of civilization, certain attributes of the required evolution between government and industrial roles in space development become easier to identify. For example, it is difficult to imagine thriving settlements on Mars that are

totally depended on government funding for their infrastructure and other major aspects of their success, such as transportation, habitation, work priorities (what people do), etc. The state-sponsored space programs of today must evolve and put in place new policies to enable a robust private industry to sustain a future where there are self-supporting settlements in space. The current government-led approach is not affordable or sustainable to support the development of space settlements, nor is there a mandate to do so. It is necessary that commerce drive the long-term sustainability of future off world settlements.

ENABLING SPACE SETTLEMENTS

Long-term sustainable space exploration is at the heart of the U.S. space strategy. In the White House document entitled ‘A Renewed Sprit of Discovery’ where President Bush describes the details of the VSE, it states that ‘*The fundamental goal of this vision is to advance U.S. scientific, security, and economic interests through a robust space exploration program.*’ (Bush, 2004). The document also goes on to say that the U.S. will, ‘*Use lunar exploration activities to further science, and to develop and test new approaches, technologies, and systems, including use of lunar and other space resources, to support sustained human space exploration to Mars and other destinations.*’. These are important aspects of the U.S. space policy that apply to future space settlements. Along with scientific and security goals, the VSE specifies an economic goal to support and sustain human presence in space by utilizing the Moon as the first

step and a proving ground to enable successful human exploration of Mars.

While there are many technological and policy impediments to this potential future, there are two major issues that inhibit both economic return and the creation of sustained space settlements; the high costs and inherent risk of space transportation and the ability of people to effectively use space resources. Although there are promising new space transportation systems under development at companies such as Space X and Orbital Sciences which may provide access to space at a much lower cost, they have not yet become a reality. Another key driver in the expanded commercialization of space is the ability of investors to control or have appropriate rights to the physical location and/or resources that they are utilizing and developing in space. For example, the tourist industry needs to ensure that their investment in land development at a resort destination is secure and legally protected. These same protections are needed for virtually any industry including those that will mine and process space materials or those that will provide services such as communication or power. Without protection of rights to use space resources it will be difficult or impossible to attract investors.

Obviously, there numerous other required enablers for space settlement including suit technology, closed life support, radiation protection, and space power. These are important second tier capabilities that must be solved, however, without affordable and low risk space transportation and protection for investments to use and develop space

resources; self-sustaining settlements of the future will not be possible.

To explore the evolution of government and industry partnerships relating to space development from the current state to a point in the future where there is an economic system supporting off-world settlements, this paper divides the process into three phases. The roles and relationship between government and industry should evolve from one phase to the next to enable sustainable settlements. Phase I is the current environment for space exploration and Phase III is the endpoint of self-sustaining settlements on Mars and outposts on the Moon described above. Phase II, arguably the most important phase, is where the role of government must transition and evolve to support long-term space settlement.

Phase I: Government-Led Exploration

In the U.S., the VSE set the goals for exploration and in response NASA developed the Constellation Program to implement a long-range architecture that will lead to sustainable human presence in the Solar System. Constellation is developing a new transportation system, the Ares family of rockets that will enable humans to go above low-Earth orbit for the first time since the Apollo program. The new transportation system will initially allow crews to travel to the ISS and then to the surface of the Moon. It is envisioned that the Ares systems created for these early mission objectives will also be part of the Mars architecture. In addition, the government is developing Lunar surface systems, such as, suits, habitats and rovers to explore the surface of the Moon. The first humans to return to the Moon will be groups of government

workers - astronauts - and the missions will be government science and applications missions. Most likely the cost of the Ares launchers will not be low enough to spark private development in space and the issue of property rights is not expected to be important to these early government missions.

Space Transportation

In parallel, an important new space policy is taking shape in the U.S. New programs have been developed at NASA and by private companies to stimulate an emerging space industry. These programs will be the foundation of the privatization and commercialization of space.

One such program is the Commercial Orbital Transportation Services (COTS) project funded under the Constellation program. COTS is defined as '*... an effort by NASA to stimulate, and then take advantage of, a robust commercial market for spaceflight services.*' (NASA, COTS; 2008). This program will enable commercial industry to service government missions beginning with the ISS. If successful, it will represent the initial transition from traditional all government-sponsored transportation for NASA human missions, to securing transportation through one or more companies that are providing these same services to other customers.

Another major development and a catalyst in the push toward privatization is the creation of the Google Lunar X-Prize, a wholly private venture for space development. In this program, Google, a publicly traded company, is providing a cash prize to encourage teams to land a rover on the Moon and complete certain

required activities on the surface. Many of the competing companies have developed business plans that are not totally dependent on winning the prize. These companies are anticipating market and revenue opportunities in providing Lunar space transportation services to governments and private industry. The relationship between Google and NASA goes even further, in that Google has partnered with the NASA Ames Research Center on strategic research projects that benefit both organizations such as applications that use Google Maps and NASA remote sensing payloads to fight fires in California. The expansion and development of the Google partnership will be a model for other private businesses that have a long-term interest in space and a desire to capitalize on the abundant opportunities.

The majority of government resources and efforts in space transportation today are going into the development of the government's Ares program, which follows in the tradition of the Apollo and Shuttle programs where the established aerospace industry is contracted by government to produce vehicles that the government has designed. Importantly, the government is in the early stages of transitioning from a producer of transportation systems to a purchaser of those services as demonstrated through the COTS program. Even more far-reaching is the entrance of private industry stimulating businesses to produce systems for deep space travel through the Google Lunar X-Prize.

Protection of Rights to Use Space Resources

The current status of private ownership or property rights in space is dominated by policies that were captured in two

treaties developed during the Cold War; the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (Outer Space Treaty) developed in 1967 and the Agreement on the Activities of States on the Moon and Other Celestial Bodies (Moon Treaty) developed in 1979 (XXXX). Both treaties forbid ownership of property in space by sovereign nations, which has precipitated an ongoing debate as to how they affect private use of space resources by individuals and private industry. The result is that the principle of property rights in space is not clearly defined and most likely any claim of rights would not be recognized by world governments. Individuals or companies interested in developing space resources are at serious risk that their investments will be challenged under the current framework.

Historically, little effort has been put forth by government to rectify this complex issue. However, there is interest outside of government as more and more people and companies start to push the issue forward because of the crucial role that property rights play in opening the space frontier. A recent article by Wasser and Jobs (2008) advocates for Land Claims Recognition a concept which would, *'...commit the Earth's nations, in advance, to allowing a true private settlement to claim and sell (to people back on Earth) a reasonable amount of lunar real estate in the area around a base, thus giving the founders of the Moon settlement a way to earn back the investment they made to establish the settlement.'* There are other approaches advocated ranging from making property rights dependent

on occupation of the site in space (Wayne White), to allowing private or government organizations to claim large tracks of space resources in order to make the development economically viable (Glenn Reynolds and Roger Merges).

Currently, space property rights remain an open issue that both government and industry need to address to develop a common understanding, approach and ultimately a solution, which promote space exploration and private industry investment. The actual negotiations to reach an international agreement could take a decade or more, which is in the timeframe of the return of human missions to the Moon.

Since Phase I and Phase III can be defined easier, they appear first in the text and not in chronological order. A discussion of Phase II follows later to explore pathways for government and industrial partnerships that will enable self-sustaining settlements.

Phase III: Self-Sufficient Settlements in Space

Phase III describes the future state as envisioned earlier where there are self-sufficient settlements on Mars and industrial outposts on the Moon. The government-industry roles have evolved to where government procures space transportation services from private industry and the issues over rights to use space resources have been settled.

Space Transportation

Space transportation has become much less risky and private companies can now make a profit because new reusable designs make it possible to amortize the production cost over multiple trips. The

spaceships carry goods at capacity during the right time in the Earth-Mars cycle to supply the thriving settlements with goods thereby maximizing profits for space transportation companies. When needed, the government procures space transportation and may act as anchor tenant to maintain an important link between Mars and Earth. Most settlers would probably not be able to travel back and forth to Earth because of the relatively high cost of space transportation and the length of time needed for the trips before returning back to Mars.

On the Moon private companies use commercial transportation to ferry their lunar products such as fuel, oxidizer, and new materials to markets on Earth, in Earth orbit, or even to Mars. The business case for Lunar developments allows companies to realize higher returns in reduced timeframes due to the use of cis-lunar spaceships which enable more frequent and varied trade opportunities.

Protection of Rights to Use Space Resources

There is a differentiation of labor on Mars, the settlers are producing the goods they need through *In Situ* Resource Utilization (ISRU) and making a living through typical free market commerce; buying and selling different goods and services to each other to ensure a thriving settlement. On the Moon, the outposts are similar to the operation of deep sea drilling platforms. They are industrial enclaves where people go for set periods of time to work on specific tasks for companies making profits from lunar activities. Development of resources on the Moon using ISRU, potentially fuel and oxidizer

and other materials developed through unique lunar processes, are used throughout cis-lunar space. Similar to Mars there is protection of rights to land and resources that enable stable development.

This future is based on the fundamental assumption that private space industry will be able to be profitable on Mars and the Moon. Bridging the gap from today's government-lead exploration approach to economically viable settlements on the space frontier can be achieved by strategically evolving the relationship between government and space industry.

Phase II: The Bridge

The Constellation program is developing a new space transportation system that will carry astronauts back to the Moon. Their visits represent the first step in the long process of research and development that will someday transform the Moon from a scientific and applied laboratory to an economic destination. As previously noted, this transformation is dependent on the ability to develop low cost space transportation for people and the establishment of rights to protect utilization of the lunar and someday Martian resources. During Phase II the government will depend on private industry for space transportation and the protection of property rights is established.

Space Transportation.

To transition from government-sponsored space transportation to a system of commercial providers there are multiple historical models that can be used as examples, such as the construction of the transcontinental

railway system or the development of passenger air travel. Both train and air travel are integral to the American way of life but both started out as strategic goals that were achieved through a concerted government plan. While the VSE provides the long-term strategy of sustained human presence in the Solar System the next crucial step is the development of plans to achieve the stated strategic goals.

Looking to history as a guide, the transcontinental railroad was developed and built by private industry, which was, in turn, subsidized by government property rights grants to the companies along the railroad route (XXX). The companies were able to realize a return on their investment and raise construction capital by selling land to settlers. Applying this model to space, transportation costs of settlers or space tourists traveling to Mars or the Moon could be recovered by Lunar land grants provided to the companies. The companies could sell the land to the settlers or other companies interested in developing resources. This is the recommendation put forth by Glenn Reynolds and Roger Merges.

Another salient example involves development of the airline industry. By subsidizing airmail in the early 1900s, Congress made aviation companies viable. The companies used the funds from airmail charges to increase the efficiency and reliability of aircraft. The program was successful and the airline industry was created and began carrying larger groups of passengers by the 1930s. The airline approach is similar to NASA's COTS program, in which NASA will pay for companies for cargo service to the ISS. However, the COTS

program has gone one step further than just buying a service, it is also supporting the development of new commercial space transportation systems. Under the COTS program the government funds multiple companies to develop independent systems for space transportation. This creates competition and provides private entrepreneurs with multiple launch options.

The complexity and difficulty of developing new space transportation systems cannot be minimized. The recent failure of Space-X's third launch of the Falcon I rocket and the difficulties that Rocketplane Kistler have had with the development of the K-1 launcher are just two examples. These companies have had development problems despite the recruitment of some of the best aerospace engineers in the world. Launch systems are intricate, complex and expensive. The challenges are vast and not unlike the development of commercialized air transportation which had its own difficult beginnings. NASA will benefit from reviewing it's roots as it develops the COTS program. Before NASA there was the National Advisory Committee for Aeronautics (NACA) which '*... helped many of the key technologies that enabled air travel to become effective, economical and safe*' (Bugos and Boyd 2008). The charter was not to create a government air transportation system, but to study the problems of flight to identify and resolve the risks that were keeping air travel from being safe and commercially viable. Under the NACA model the government worked closely with industry to fund studies that retired technological risks and enabled private enterprise to successfully create a new industry. Similarly, Government, in

partnership with industry, could fund studies that work to identify and retire the risk of space transportation until companies are able to gain a foothold in space.

To fulfill the mandate in the VSE, NASA is building the Ares family of rockets and providing incentives for entrepreneurs through the COTS program. New approaches to encourage development of low cost, low risk space transportation can be modeled after past government supported successes like the transcontinental railroad or the commercialization of the airlines. In addition, there can be advantages to considering the NACA model to help build a new space transportation industry. A deliberate strategy and plan are needed during the next phase of exploration to enable private industry to access and utilize deep space and create the framework to support the development of sustainable settlements and outposts.

Protection of Rights to Use Space Resources

There is also a heightened level of complexity when approaching the issue of land and resource rights. Undoubtedly, it was easier in the past when conquest gave governments relatively simple methods to claim legal ownership over new lands won through aggression. But this approach is no longer viable in the internationally connected world of today. To enable sustainable settlements in space there will need to be a push from industry to demand that their rights to develop and use space resources are protected before major investments can be responsibly made.

Before the VSE and the most recent push from multiple countries to explore the Solar System, the question of property rights in space was largely an esoteric subject with little interest in the space industry or in government. The Outer Space Treaty and the Moon Treaty leave the question of property rights of private individuals and companies open to interpretation. Without strong economic incentives, which outweigh the risks to investors creating enterprises that require the use of land in space, there will be no development on the Moon, Mars or other space objects.

In an analogous area of mining the deep ocean bottom in international waters for hard minerals, the U.S. made its own rules in the Deep Seabed Hard Mineral Resource Act passed in 1980. Under the act the U.S. issues its own licenses and permits and '*ensures protection of the marine environment, safety of life and property at sea, prevention of unreasonable interference with other uses of the high sea and conservation of mineral resources.*' (NOAA). The use of space resources could be similarly regulated and protected allowing for responsible utilization.

A better approach, though more difficult to achieve, would be the establishment of an international regime by treaty that could manage a licensing or permit system to protect the rights of individuals and companies in space. This may provide stronger protection for investors because of its international nature and the recognition from many countries to the regime's right to oversee the use of space resources.

No matter which route is taken it is essential to provide protection of the

rights for individuals and companies to use space resources. Government will need to take the lead by either creating legislation or negotiating a new treaty. But it will be industry that will drive the process to ensure that the new regime will facilitate the development of space.

CONCLUSIONS

Someday there will be sustainable settlements in space. The direction set forth in the Vision for Space Exploration provides the context for the role that government will play in taking those first steps off the Earth. The real work will be done by private industry. There are two primary areas where the policies and relationship between government and industry must evolve to achieve sustained settlements on the Moon and Mars; space transportation and rights to use property and resources in space.

As the Constellation program takes humans back to the Moon and on to Mars, there will be a necessity to open the frontier beyond government employees. Enabling sustainable space settlements will require a change in the relationship between government and industry. In space transportation the government will go from a developer to a facilitator and customer. In order to enable private investment, the governments of the world will need to develop a set of policies that will protect the rights of industry to use land in space and to develop resources. Only when these two conditions are satisfied can sustainable settlements in space be seriously considered.

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