An Economic Based Strategy for Human Expansion into the Solar System

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ABSTRACT

Over the years several visions have been advocated for human expansion into the Solar System. To date these space settlement visions have approached the challenge from a physics perspective rather than one based on economics. Usually these visions are built around an assumption of massive government funding and a national commitment to human expansion into the Solar System. As a result, these visions have only remained visions in books, articles, and presentations. This paper approaches the challenge of human expansion into the Solar System from a completely different perspective, an economic one using strategic approach. This approach allows the crafting of an economic development based space strategy that starts with the existing economic situation and provides a practical road map for human expansion independent of dedicated government funding.

PAPER

1 Introduction

Several authors have described the desirability of establishing human settlements on Mars, the Moon, the Earth-Moon LaGrange Points and Earth orbit. One of the first was by Konstantin Tsiolkovsky who in 1903 talked about humans building habitats for living in space (Heppenheimer, 1977). J. D. Bernal speculated in the 1920's about building large spheres, now called Bernal Spheres, that would serve as cities in space (Bernal, 1929). In the early 1960's Danridge Cole envisioned hollowing out asteroids to serve as human settlements (Cole and Cox, 1964). Krafft Ehricke in the 1960's proposed the creation of communities on the Moon (Ehricke & Freeman 2009). In the early 1970's Gerald O'Neill argued for building large rotating settlements in space, particularly at the L4 and L5 LaGrande Points (O'Neill, 1976). In the 1980's Robert Zubrin provided strong arguments for humans building settlements on Mars, a vision known as Mars Direct (Zubrin, 1997). In the early 2000's Al Gobus proposed the Kalpana One habitat as a first step towards space settlement (Gobus et al, 2006). Although these visions of space settlement have attracted large number of followers, especially the visions of Gerald O'Neill and Robert Zubrin, they have failed to advance beyond being simple visions. Robert Zubrin's Mars Direct Plan (Zubrin, 2016) has shown the most progress beyond the initial vision because he did outlined a basic strategy for implementation and created the Mars Society to fund Earth analogs to conduct some of the preliminary research, but it has failed to move much beyond that promising start in the last two decades although Elon Musk has lately invested in it (SpaceX, 2021).

2 An economic based approach to space settlement

There are three primary reasons for these visions of human expansion in space have failed move forward. The first is that these visions have looked at human expansion into space from the narrow perspective of technology, ignoring the economic and legal environments that have historically been the primary driver of advances in technology (Bernstein, 2010). Second, other that Robert Zubrin's Mars Direct (Zubrin, 2016), none have offered a real strategy for implementation beyond some vague outlines. Finally, all are dependent on reliable inexpensive access to space to move beyond being mere visions to actual strategies, although Elon Musk's Starship/Super Heavy (SpaceX 2021) may finally be moving launch technology in that direction. The result has been a century long stagnation in the dream of expanding humanity into space.

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Historically the economic and legal environments have been the primary drivers of the development of technology. Hero of Alexandria's steam engine (Bernstein 2010) is a good example. Although having the potential to launch a new path of technology development it never advanced beyond being a historical curiosity because the economy of Roman had no need for it and there was no legal concept of intellectual property to encourage its development. By contrast, the emergence of the steam engine in England resulted in a technological revolution both because of the economy of English, which needed a practical way to pump water out of mines, and the protection of intellectual property provided by the patent laws of the 17th Century (Bernstein, 2010). Similarly in China development of the printing press was limited by an economic and legal system that gave the Emperor of China a monopoly on all inventions (Pomeranz, 2000). The Emperor of China restricted its use to printing government documents, money and approved works of knowledge limiting its impact on society. By contrast the rediscovery of the printing press in Europe, under its economic and legal system, resulted in its widespread adaption throughout the region leading to its constant improvement while launching an information revolution (Pomeranz, 2000).

If a space settlement vision is going to be transformed into reality it must take into consideration both the economic and legal environment when they are formulated. Although some have proposed economic justifications for these proposed space settlement visions, for example building solar power satellites to transmit energy to Earth, they have been mere after thoughts, not the drivers of the vision. Another common feature is all of these visions look to the government as the primary, if not only, financer of human expansion into space despite history showing that in the West human expansion into new regions has always been enabled by private financing with governments giving only limited financial incentives in the form of concessions, limited seed financing and creating a favorable legal environment (Pomeranz, 2000). Usually these incentives are driven by considerations of national security. Next, these proposed visions require reliable and inexpensive access to space prior to being implemented ignoring the economic factors that ae needed to drive its development. Finally, other than for Mars Direct and Kalpana One, there are no estimates or even basic lists, of what will be required to actually create the proposed settlements so there is no way to determine either the cost of implementation or the point to which space launch costs must be reduced to transform these visions into realities.

A strategic approach to human expansion into space must first start with an analysis of the economic and legal environments. This is the basic difference between a strategy and a vision (Rumelt 2011). A vision is merely a description of a desirable outcome or destination. A strategy is a roadmap of how to reach the desired destination or outcome from the existing starting point (Rumelt 2011). This requires analyzing the existing economic and legal environment. It also requires the making of two assumptions about human expansion into space. The first assumption is that human expansion into space is defined by the establishment of sustainable communities in open space and/or on the surface of Celestial Bodies. A sustainable community is a community capable of supporting itself economically, producing the majority of the basic goods it requires, including food, to survive indefinitely, and having a sustainable core population of humans who are producing children at a rate sufficient to maintain the population. Anything else should be viewed as being a base, research facility or other form on non-sustainable human community. Second, since historically private finance has been the primary source for human exploration and expansion into new regions in the West it will also be the source of funding for human expansion into space. The lack of interest in Western space agencies over the last 60 years to provide more than token funding for research on space settlement confirms the validity of the second assumption.

Once these assumptions are accepted it is necessary to analyze the economic and legal environments that will provide the framework for establishing space communities. Of the two the legal environment will be analyzed first. The four basic treaties (UNOOSA 2021) that define international space law, along with the legal precedents established, provide a very favorable framework for building sustainable space communities outside of nations that are party to the Moon Agreement. Article VI of the 1967 Outer Space Treaty outlines clearly that the nation(s) that are home to a space endeavor are responsible to regulating it. In the United States, and the majority of the nations that have signed the Artemis Accords (NASA 2021a), this is a favorable environment by providing statutory and legal precedents for economic benefits, especially Intellectual and Chattel Property Rights needed to create economic value for the output of space communities.

In terms of the economic environment space communities must be able to privately fund their own development. Private financing of space community research could be divided into four categories, sponsorship, donations grants and commercial. Sponsorship would be in the form of either members paying dues to cover the research or individuals/organizations providing funding in exchange for recognition for support. Donations would be individuals/organizations simply giving money to the endeavor. Grants, from governments or private entities, would be linked to specific projects with clear outcomes and timelines but not necessarily a financial return on investment. Since these sources would have no expectations for a return on investment, they would be most suitable for startup funding. But because there is no focus on a return on investment the amount of funding would be limited. Commercial funding, which would represent the largest pool of funds available, would consist of loans and investments but would require the endeavor demonstrating the reasonable ability to pay back the loan or provide a return on the investment. It would only be used in those portions of the endeavor ready for commercialization.

This creates the requirement that research on building space communities must generate Intellectual and Chattel Property that has a market value if it will be able to scale up beyond basic research into its feasibility. Matula and Greene (2016) show how the environmental crises humanity is currently seeking solutions to presents a near term potential market for the technology needed to build space communities. The means that the initial element of a strategy for human expansion into space must focus on these early potential markets. Future elements of the strategy must then focus on the potential of future markets for generating Intellectual and Chattel Property sufficient to cover the commercial funds required. This means a strategy for human expansion into space falls naturally into four levels, each level providing the foundation for the level above it (Matula and Greene, 2014). These levels are Earth, Near Earth Space, Solar System, Beyond the Solar System. The Astrosettlement Development Strategy Proposed below is based on these four natural levels of development.

3 The Astrosettlement Development Strategy (ADS)

The Astrosettlement Development Strategy (ADS) consists of the four levels that derive from an economic based approached to human expansion into space. It provides a roadmap for human expansion into space that starts out with activities that could be started today with only modest private funding. The four levels described in detail below are 1) Earth Based Research, 2) Lunar Industrialization, 3) Developing the Solar System, and 4) Interstellar Migration

3.1 Level 1 – Earth Based Research

The ADS starts out on Earth with the focus on developing the technology required to make space settlements. This is the component that is missing in most existing space settlement proposals. The result the focus has been entirely on reducing the cost of spacelift, a necessary but not sufficient prerequisite for space development. The Level 1 emphasis is on development of the habitat designs, space agriculture and the robotic systems needed to make space settlement practical, affordable and sustainable. The revenue and technology generated on this level provides the financing and capability to advance to the next level.

3.2 Level 2 – Lunar Industrialization

The critical next level is the industrialization of the Moon. The greater the mass of raw materials available from lunar resources the less mass will need to be lifted from Earth. This is the key to the economic development of space, minimizing the mass launched from Earth to only the initial technology needed, complex but low mass components and humans emigrating to space. Although asteroids have the potential to also provide resources for space development in the future, the time lag from the large distances to them along with the variable transit time make then far less attractive for the early phase of the Astrosettlement Development Strategy. Unlike asteroids, the Moon is close enough to use telebotic labor to supplement local labor in locating and developing its resources. The rapid transit time to the Moon from the Earth also facilitates both the transportation of needed technology and the shipment of lunar goods to the Earth to cover the costs of industrialization. The focus of this level is creating the lunar industrial capacity needed to build future habitats in space which could then be used for expanding the economic sphere of humanity beyond Cislunar Space into the Solar System.

3.3 Level 3 – Developing the Solar System

The increasing capability of lunar industrialization provides the economic foundation for the development and settlement of the Solar System. This will be accomplished by the building of large mobile space habitats near the Earth-Moon L1 and L2 locations. These are large (1 km diameter or greater) mobile self-sufficient 1G habitats capable of slowly traveling to any location in the Solar System (Matula 2014). Since they are self-sufficient transit time will not be a factor in reaching their destinations, allowing them to use low energy orbits. Once these mobile habitats reach their destination, they will be capable of expanding their size or building additional habitats from local materials on either the local Celestial Bodies or in open space. This level covers the settlement of the entire Solar System out to the Kuiper Belt.

3.4 Level 4 – Interstellar Migration

The fourth and final level will be when the mobile space habitats technology is combined with advance propulsion systems to enable space settlement to move beyond the Kuiper Belt to the and Oort Cloud. As Asimov (1967) discussed mobile self-sufficient space communities could simply hop from one Oort Cloud object to another over thousands of years until they reach the Oort Cloud of an adjoining Star System much like migrating hunter-gathers reached the Americas from Asia. Alternately, by the time the Oort Cloud is reached the propulsion technology could advance to a point that would allow mobile space habitats designed for the Oort Cloud to be transformed into the first generational starships. At a speed no greater than 4% the speed of light these generational starships will enable humanity to expand over the next thousand years throughout this section of the Milky Way. Since the technology of these mobile space systems are based on using resources from small asteroid and comets habitable planets will not be a requirement for human settlement of a start system.

The ADS strategy outlined here provides a roadmap that starts out with only a modest private investment to one allow human space communities to advance to interstellar space on the successful economic development of the earlier level. This evolutionary approach reflects the iterative process that has driven human progress throughout history to create the existing global economy (Bernstine, 2010). It also provides a solution to the major problem of earlier space visions by providing a starting point for implementing the road map independent of government funding or reliable inexpensive access to space.

4 Starting the journey

Using the assumptions of private funding and no access to space Level 1 starts out with activities that have the potential to return a near term on investment before the establishment of communities in space. The first activity that satisfies these criteria is the development of computer simulations of the proposed space communities to determine their social and economic interactions. Implemented as an online role playing game it would create a community of virtual space settlers on Earth that would provide valuable information for developing future elements of the strategy. Development of the game would likely be in the few hundred thousand of USD, an investment that could be generated through subscription fees and merchandising. Modest as it is, it would begin the implementation of the Astrosettlement Development Strategy.

This first element of Level 1 would be followed another element focusing on developing a research agenda for space agriculture, determining the species the plants, insects and other organisms that will be needed by space communities. Agriculture will be the critical technology driving of the economies of space communities both internally as well as externally requiring a large portion of both their raw materials and labor needs. To date no substantial research has been done on determining exactly which of the thousands of domestic plants will be needed to supply the basic needs of space communities or identifying the insects and other organisms that will be needed to support and supplement the plants selected (Matula and Greene, 2016). Since the production of food will likely require a majority, perhaps as much as two-thirds of the pressurized space in a space habitat this is a critical piece of information that will be essential to their design and construction. Basic questions as to the amount of area needed for sustainable agriculture, the energy, water and nutrient requirements, the skill level and amount of labor are directly dependent of the specific mix of species of plants selected and their adaption to the high density artificial environments of space habitats. Although NASA has been doing some generalized research on supplementing food supplies from Earth by locally produced plants on space missions (NASA 2021b) the research has not been approached from the systematic perspective needed to answer even the most fundamental questions related to creating a sustainable and nutritional cuisine for communities in space. Other unanswered questions relate to the plants, insects and other organisms needed to produce necessary industrial materials for space communities, a key element of agriculture on Earth. Finally, it will explore if there are agricultural products, perhaps like wine, that might serve as export goods for space communities.

Answers to these questions have applications on Earth as well as for future space settlements. Earth based agriculture is seeking ways to increase yields and isolate itself from water shortages and climate changes (Matula and Greene 2016). This means the Intellectual Property generated from developing the technology needed to enable space communities will have market value on Earth, enabling the financing of the line of research. It is also a research agenda that lends itself well to creating a research community on Earth comprised of academics, advocates and STEM students dedicated to moving the technology for space communities forward. In doing so I t provides a mechanism for involving the general public in the development of communities in space.

Finally, the design and construction of analog facilities on Earth to integrate and advance the technology needed for space communities will create both Intellectual and Chattel Property that will generate near term revenue through commercialization of the technology for building communities in remote environments on Earth or offshore of major urbans areas. For example, the high yield agriculture modules being developed for space could serve as models for floating farms offshore of urban areas like New York or Los Angeles providing a local, greenhouse gas free source of fresh fruits and vegetables. Similar habitats will make life in desert and arctic areas more desirable allowing the human population to disperse from coastal and high value agricultural land.

5 Conclusion

The difference between a vision and a strategy is that a strategy provides a roadmap to its implement from the existing starting point. The Astrosettlement Development Strategy (ADS) satisfies this criterion by starting with Earth based research, not space, as its first level. Earlier visions merely focused on the generic benefits of human settlements on Mars, the Moon, the Earth-Moon LaGrange Points and Earth orbit in more abstract terms like the survival of humanity or importation of space resources for use on Earth. The massive costs of the first step required for these visions, the actual building of settlements, makes the development of a strategy for implementation impractical. By contrast the first level of the ADS starts on Earth with the development of technologies that will not only make space settlements sustainable but will also make human communities on Earth more sustainable by reducing their impact on the environment. In doing so it generates near term revenue streams that enable private financing to begin the human journey to the stars.

ACRONYMS

Acronym	Description
ADS	Astrosettlement Development Strategy

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