Advanced Financing Models For Large Scale Space Infrastructure And Habitation

This paper was prepared as background for a panel of the same name presented at the **Beyond Earth Symposium**, on October 13, 2022. The content of this paper was informed by but does not necessarily represent the views of any of the speakers on the panel or their employers.

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I Introduction

We are in the midst of a new space economic renaissance, with investment money flowing from private and public sources like never before. This investment is spurring a new wave of space innovation and applications that will benefit the world economy. But, while these investment trends are enabling such growth in the space-related markets, it remains unclear how we will eventually finance the construction of large-scale space infrastructure elements needed to support extensive cislunar activities, such as in-space servicing, assembly, and manufacturing (ISAM), mining and other in situ resource utilization (ISRU) operations, space-based solar power, and large-scale human habitats. The current funding mechanisms for space development are insufficient to meet this next stage challenge, which could be upon us within this decade.

In this paper, the Beyond Earth Institute will consider the financing options that could be made available to the developers of large-scale space infrastructure and habitat projects. Sooner or later, future space development planners will have to confront how to finance such mega projects.

We hope the financing options and models examined in this paper, many of which helped finance terrestrial infrastructure projects, might apply to the space environment. These options are not meant as an all-inclusive roster. There are undoubtedly even more novel models worth pursuing that match the audacious ambitions of establishing economically viable communities beyond earth. Of course, identifying a large enough customer base to justify the appropriate upfront non-recurring capital investment is fundamental to any successful financing model. To that end, the authors of this paper recognize that translating the vast potential of space-based markets into reality is still very much a work in progress. But, given the rapid upsurge in private and government-financed innovative space ventures seeking to commercialize the benefits of space, it is not too early to explore equally innovative large-scale financing models.

II What is Meant by Large-Scale Space Infrastructure and Habitats?

We are rapidly developing the means to access the solar system's resources that will, by the end of the century, create a space economy many orders of magnitude larger than any near-term space market estimate. This growth will result from extensive in-space mining, manufacturing, and habitation activities. Examples include but are far from limited to:

- Advanced high density and low latency communications satellite networks
- Advanced power generation sources for in-space and planetary surface operations
- Capability to mine water and minerals from the Moon, Mars, and asteroids
- Ability to efficiently transport resources to the desired location throughout the cislunar environment, including earth
- Capacity for in-space mining operations that will feed in-space manufacturing of finished and semi-finished goods for delivery to locations in space and on Earth
- Large-scale human habitats on the Moon, Mars, and in free space for semi-permanent occupancy

The above projects would have seemed too far out just a decade ago. Today, they are generally accepted as reasonable future initiatives. But financing these projects will require tens of billions of dollars or more, far exceeding the appetite of private and public investors, with few exceptions. As we anticipate implementing such mega space projects, it's appropriate to ask, 'how are we going to pay for them?' What will the structured project financing models look like?

This future is emerging. The only question is whether or not our national and international policies are willing to accept and support this future or remain an impediment to it. The nations and private investors who embrace this future will reap the rewards.

III Traditional and Advanced Financing Options

Historically, the U.S. government has wholly sponsored space research and technology development. Direct U.S. appropriated funds have paid for the Apollo moon program, the Space Shuttle, and the International Space Station. Only in the past decade or so has NASA looked to systematically share the development costs with the private sector. Private investment is also changing the calculus of space research and development. SpaceX, Blue Origin, Virgin Galactic, Sierra-Nevada, Northrop Grumman, L3 Harris, Voyager Space, and many others are making massive investments to drive space technology and expand the capability to new levels.

As we look ahead to the massive investment that will be needed for in-space infrastructure and habitation, it's clear that the availability of direct government funding is limited. NASA's budget in Fiscal Year 2022 is $24 Billion, short of the 7% increase proposed by the Biden Administration, and we can only expect incremental gains over time. DOD and the U.S. Space Force are also increasing investments in space capability. But, even these levels are nowhere near sufficient for future challenges alone.

Fortunately, various creative, innovative mechanisms can be employed to structure the necessary financing for even the most expansive space projects. What follows is a menu of options that the U.S. government, the international community, and investors can consider as part of a comprehensive financing plan.

Public Private Partnerships

Until the mid-aughts, NASA primarily contracted with industry partners on a cost-plus basis for all hardware developed. While there are benefits to this kind of contracting, it creates a strong disincentive to bring down the cost of space systems and launch critical elements in the potential for space commerce. In 2006, NASA experimented with a dramatically different approach under the Commercial Orbital Transportation Service (COTS) agreement. The program was an unqualified success. For an investment of just $800 million, COTS resulted in "two new U.S. medium-class launch vehicles and two automated cargo spacecraft." The subsequent Commercial Resupply and Commercial Crew programs to deliver supplies and astronauts to the International Space Station were equally successful. NASA has also applied this Public Private Partnership (PPP) model to lunar exploration programs, such as CLPS, Volatiles Investigating Polar Exploration Rover (VIPER), and the Artemis Human Landing Systems. NASA will continue to utilize this model. Indeed, there is solid bi-partisan interest across the government, including with DOD, to employ PPP to achieve technical goals.

The key drivers of this success were that these PPP programs not only shared the cost of system development with the private sector, allowing investors to achieve an acceptable risk-adjusted return on investment, but they also offered large initial markets for the services to be provided by these space systems. Reducing early-stage market risk is critical for successful large-scale infrastructure financings. The PPP programs also differed from past practice by funding two or more capabilities, thus creating new industry sectors to compete and innovate into the future versus one time government-funded, sole-source capabilities with a limited life.

For a mega space program, PPP could be part of the financing mix, assuming that such a project was a priority for the partnering nation(s). But, considering the limits to which partnering nation states may be willing to invest, PPP should be regarded as just part of a large mix of financing elements.

Private Investment

Data from Space Capital shows investors poured nearly $15 billion into the sector in the first half of 2021 alone across 230 deals, $37 billion since 2013. Such growth is immensely encouraging for entrepreneurs and investors in the space sector. Quality Analytics associate Jeff Thoben said space investment is "reaching near-manic levels" as private equity consolidator activity also ramps up in the market.

The investment environment for space ventures has never been better. Most investors are appropriately focused on relatively near-term ROI from low Earth orbit investments.With that said, the authors recognize that the current investment climate is dealing with "headwinds" such as inflation, rising interest rates, continuing effects of the recent pandemic, and recessionary fears that might, in the near term, cause some pullback by the investment community. But we remain confident that the fundamental long-term trend lines for space investment will continue on an upward slope - notwithstanding the occasional downturns due to macroeconomic business cycles.

Any sound business model showing a suitable investment return will attract investors.

It is not likely that private investment alone could be raised for mega space projects such as lunar infrastructure or large human habitats. Such investors would want to know how much government contribution (either in direct funding or as an anchor tenant) or other project financing elements were involved in helping manage the risk. Again, while private investors will ultimately be part of the mix in financing large-scale space projects, they will likely seek as much public support as is available for the foreseeable future.

SPAC - Special Purpose Acquisition Company (SPAC)

A SPAC is a shell corporation with no active business operations and whose primary asset is cash to make an acquisition of an existing company. SPACs are used as a financial instrument to raise capital from investors through the channels of an initial public offering (IPO). The funds raised from the IPO are then used within a one-to-two-year period to finance ventures, such as acquiring private firms and taking them public or merging with startups to provide them access to long-term affordable capital to finance infrastructure development and expansion. The importance of SPACs has been an initial opening of the public capital markets to commercial space investment. The public capital markets provide liquidity, creating a perpetual source of capital. In contrast, most private equity financings come with investment horizons where investors seek an exit within generally 5 – 10 years, a period often too short for the space markets to have developed sufficiently to provide a satisfactory risk-adjusted return on capital.

In recent years, they have initiated a boom in the space startup sector, placing startups within reach of additional funding and enabling a smoother trajectory to public listing through mergers or SPAC deals. In 2021, nine space companies went public through SPAC mergers.

Enthusiasm for SPAC as a vehicle for a rapid cash infusion to space ventures decline in late 2021. Dampening interest are new regulations issued by US Securities and the Exchange Commission (SEC) that have added complexities that investors see as an added risk to the model and the poor stock trading performance of many of the SPACs that have made their acquisitions and begun operations. This has sparked uncertainty, resulting in delays, additional paperwork for the IPO processes, and a lower current investor appetite for new space-focused SPACS.

SPACs will likely remain an option for commercial space projects. (For example, Intuitive Machines just announced it would list on the Nasdaq after merging with the SPAC Inflection Point Acquisition Corp for a valuation of $815 million.) SPACs have already injected billions into the space market, a positive development. As more advanced mega space projects are initiated, some commercial elements of such projects will likely be financed via SPAC IPOs.

Government Debt Guarantee, Subsidies, Tax Incentives, and Direct Lending

The employment of debt guarantees, subsidies, tax incentives, and direct lending are ways the U.S. government has supported industries and business types to meet many objectives. Such options could similarly be employed to support space activities.

Loan/Debt Guarantee - A loan/debt guarantee is a contractual obligation between the government, private creditors, and a borrower—such as banks and other commercial loan institutions—that the Federal government will cover the borrower's debt obligation if the borrower defaults. Government loan/debt guarantees eliminate the default risk to the lender by shifting it entirely to the government, enabling the borrower to obtain much more favorable loan rates. Often, without the guarantee, the loan would not have been approved at all. In other cases, the interest rate would have been higher. The question is how much debt the government would be willing to take on to support space infrastructure development. The Transcontinental Railroad was financed in part with such government guarantees and subsidies.

Subsidies - A subsidy is a benefit given to an individual, business, or institution, usually by the government. The subsidy is typically given to remove some burden, and it is often considered to be in the overall interest of the public, given to promote a social good or an economic policy.

i. Low-interest loans, tax incentives, and many government welfare programs are indirect subsidies

ii. Examples of Subsidies - a payment from government to private entities, usually to ensure firms stay in business and protect jobs. Examples include agriculture, electric cars, green energy, oil and gas, transport, and welfare payments.

Tax Incentives - The tax code could be used to stimulate space development. Utilizing the tax code can be attractive to some lawmakers because of its simplicity to manage; however, in the past, other lawmakers have argued that the space industry should not be singled out over other important emerging industries. Any eligible entity can claim the incentive when filing their taxes. In the current space investment environment, the parameters for eligible projects may need to be defined as those that extend beyond low Earth orbit, as the LEO economy is experiencing a boom not requiring such incentives. Forms of tax incentives include:

i. 'Zero tax for zero G' has been a popular recommendation among space advocates. If a business involves putting assets into space, it would not have to pay taxes on its profit. Perhaps the slogan could be modified to 'Zero tax beyond LEO.' Actual corporate tax liability is currently so low in the U.S. it is hard to see how such an incentive would motivate extensive investment beyond what is already taking place as it does not share upfront development costs or lower market risk.

ii. Corporate tax credits would be a more significant stimulating effect, as certain expenses would be deducted from the tax liability and potentially result in a tax refund. But, again, we would want to define the kind of expenses that would be eligible clearly. There is no need to stimulate a burgeoning market further.

Direct Lending - Direct lending is the provision of credit directly to small and middle market companies (SMEs) for growth or acquisitions. Government is able to take higher risks than traditional lending institutes. It's a variation on loan guarantees that could reduce the overall cost to the government. It also creates a bureaucratic challenge that lawmakers may not want to put on existing agencies. For example, loans from Export-Import Bank (Ex-Im Bank) provide debt for satellite financings are well established.

i. Ex-Im Bank loans are generally lower cost than what is available in the traditional commercial lending market but do come with lots of restrictions and a high up-front cost in fees and due diligence. Since Ex-Im loans have been in the hundreds of millions of dollars, they would be stretched to fund projects requiring billions.

ii. Ex-Im loans generally have maturities of 8 years or so, which has been a long enough period to generate sufficient positive cash flows in the satellite industry to cover debt servicing. Some space infrastructure projects involving less developed markets might require much longer maturities, such as the 12 years frequently offered by the US International Development Finance Corporation (DFC). More details regarding the DFC are below.

These government-sponsored mechanisms could come into play for large-scale investment. These are not likely to be employed until there is an obvious project definition, which will be necessary in order for the terms of the government programs to be drafted. These mechanisms will likely place restrictions to benefit the sponsoring countries.

Again, these favorable funding sources are part of the long-term financing mix and not likely to account for all the total needed financing.

Lunar Development Cooperative[1]

The US can lead in the creation of a public-private partnership infrastructure company that would enable public and private entities to cooperatively and affordably gain access to locations and resources on the Moon. We call this the "Lunar Development Cooperative" (LDC). The U.S. Government would supply an initial capital equity investment to start the LDC. The US would also invite other nations to make similar equity investments, with developing countries eligible to purchase stock options. It would invite private-sector investors to take up a majority of the LDC's stock, including companies, high net worth individuals, and even regular citizens of any financial means. These investments would have a long-term rate of return, allowing the government investors to generate a profit to refund taxpayers while also de-risking the investment for private-sector parties.

The LDC generates income from the rise in the value of locations in space, benefiting from its shared infrastructure over time. For instance, if the LDC built a landing pad on the moon, alongside a power supply, shared-use habitat, and closed-loop life-support systems, it would earn revenue from this infrastructure over the long run through the rise in the use value of the locations on the Moon benefiting from the infrastructure. This long-term value would be captured through market-priced service-access licenses that require the user to pay for the market-determined rental value of the location they occupy while using LDC services.

Strategic Propellant Reserve[2]

One way to stimulate the space market is through the creation of a strategic propellant reserve. It can be propellant, water, minerals, or any other valuable and sought-after resource, strategically located in orbital space or on the lunar surface. In the event of an in-space shortage for such 'commodities,' authorities would have access to these reserves so as not to disrupt the flow of activity. The strategic reserve could be made available to government and industry as needed. Similar to the Strategic Petroleum Reserves, which acts as a buffer against any sudden disruption in the oil market. Strategic reserves can be financial in nature or even stockpiles of finished goods considered strategically important.

According to SSR leading proponent, United Launch Alliance CEO Tory Bruno, a Strategic Propellant Reserve by 2050 could stimulate a space-based economy of $3 Trillion, of which the propellant activities alone would account for $630 Billion. All of this, he says, could be made possible with a government investment of about $20 Billion.

Strategic Space Reserves and Space Commodity Exchange[3]

The Space Commodities Exchange is an idea promoted by Bruce Cahan of Stanford University. Part of the appeal is that the required government obligations would largely consist of legislative approval, regulation, and oversight versus significant funding. A space commodities exchange would allow buyers/users and sellers/producers to enter into forward contracts for the purchase and delivery of commodities in space at various defined locations. As Cahan wrote in a recent report:

"Space commodities allow the space economy to evolve and rely on standardized definitions of the goods and services they produce and need to operate in, from and to space orbits and regions of interest. The Exchange would reveal detailed levels of demand for specific space commodities in Earth orbit, near-Earth asteroids, cislunar, and beyond. Space companies would be permitted to earn cash flow via commodity contracts sold now for delivery in the future and would create a level playing field of Exchange Member Rules by which competitors agree to abide. The Exchange would allow for more open bidding that would drive better price/performance ratios for government and private sector users. Furthermore, if a customer were to buy too much of a given space commodity, the Exchange would allow for the re-sale of the commodity to achieve liquidity and flexibility in planning and adjusting future space operations. The Exchange would speed government acquisition of generic, commercial off the-shelf (COTS) space commodities at lower technology readiness and reliability risk to ensure the functional use of specific space commodities …The Exchange will, among other things, require the US government to better understand and forecast its aggregate demand for space-based commodities."

In general, however, commodities exchanges work best when there is first a known and mature market for the commodities being exchanged. As such, a space commodities exchange may work best when coupled with a strategic space reserve as a major anchor customer to generate initial market demand. Strategic space reserves could support NASA exploration initiatives, future anticipated needs of the U.S. Space Force, and similar needs of other space agencies and countries.

Flow-through shares (Canada)[4]

The flow-through share program in Canada that supports their oil and mineral exploration companies is a possible model to support space infrastructure and large-scale habitat financing.

Flow-Through Shares are a special issue of common shares where the early losses from prospecting, infrastructure development, and initial operations are passed directly to shareholders as tax deductions and then become regular common shares after the tax deduction is completed. Corporations that issue FTS typically generate Canadian Exploration Expense (CEE) which is a 100% deduction against income.

Flow-through shares are a financing tool available to a Canadian resource company that allows it to issue new equity (shares) to investors at a higher price than it would receive for "normal" shares, thereby assisting it in raising money for exploration and development. This then reduces the investor's Canadian taxes. The U.S. and other governments have resisted this idea, fearing that other industries would demand similar treatment. In addition, the U.S. has different ways of supporting oil and gas exploration.

Flow-through shares is an exciting model that could potentially support space infrastructure projects.

Development Finance Corporation Model[5]

The United States International Development Finance Corporation (DFC) is the development finance institution of the United States federal government, primarily responsible for providing and facilitating the financing of private development projects in lower- and middle-income countries. A DFC devoted to financing space projects could similarly be created.

This DFC Model for space has been proposed by the National Space Society called the Outer Space Private Investment Corp. (OSPIC), which mirrors the very successful Overseas Private Investment Corporation (OPIC) funding for infrastructure investments in emerging economies. The idea was that you could replace "overseas" with "outer space" in the OPIC charter without altering any other aspect. Space would simply be viewed as another geographic area of importance to the U.S. that had an economy too risky to attract private investment in much-needed infrastructure. In the OPIC case, investment in roads, hospitals, utilities, water treatment, telecom, and other primary infrastructure necessary for the economy to support its population and business development for stable markets to emerge and grow.

The question for OSPIC is whether it could evolve to sufficiently cover the cost of major infrastructure and habitat projects in space. DFCs are well suited

1 More on the LDC concept can be found at https://www.thespacereview.com/article/3928/1 or at https://youtu.be/qP8hGoNY9dk (accessed on July 19, 2022)

2 Users' Advisory Group. (2020, September 3). National Space Council. Assessing the Utility of a U.S. Strategic In-Space Propellant Reserve: Economic Development. Retrieved from https://www.nasa.gov/sites/default/files/white_paper_on_strategic_in space_propellant. (accessed on July 19, 2022)

3 B. Cahan. "Space Commodities Futures Trading Exchange: Adapting Terrestrial Market Mechanisms to Grow a Sustainable Space Economy" New Space Magazine https://www.liebertpub.com/doi/abs/10.1089/space.2017.0047 (accessed on July 19, 2022)

4 Suarez, Steve. (2021). Mining Tax Canada. Flow-Through Shares: Executive Summary. Retrieved from https://www.miningtaxcanada.com/flow-through-shares/ (accessed on July 19, 2022)

5 Position Paper: Outer Space Private Investment Corporation (OSPIC), National Space Society https://space.nss.org/wp-content/uploads/NSS-Position-Paper-Outer-Space-Private-Investment-Corporation.pdf (accessed on July 19, 2022)

for investing in smaller companies and projects and may not be well suited to massive investments in space.

DFC can also invest directly in infrastructure funds focused on emerging companies as debt capital up to 30% of the total size of the investment fund. This low-cost debt capital allows the 70% equity capital to achieve a higher return on capital for these riskier markets. If nothing else of the OSPIC idea is achievable legislatively, this one aspect would be beneficial.

Space Trade Agreement

The Administration has the authority to request the US Congress grant the US Trade Representative "Fast Track" Trade Promotion Authority (TPA) to commence negotiations with our international space & trading partners, e.g., the European Union, UK, and Japan, the purpose of which is to establish the "Rules of the Road" for the trade and investment in off-planet commerce.

A Space Trade Agreement (STA) should include all interested current and future spacefaring nations. The STA should address all the economic and jurisdictional/enforcement issues today, providing the needed certainty for popular investment and business expansion tomorrow. This STA should effectively bring all off-planet business activities into the international trading system. It should also seek to mitigate future disputes among nations competing for scarce space resources through the World Trade Organization in lieu of conflict.

Inmarsat model[1]

Inmarsat is a private British satellite telecommunications company offering global mobile services. Inmarsat, however, began as an intergovernmental non-profit organization in 1979 created to establish and operate a satellite communications network for the maritime community. Twenty-eight nations joined in forming and funding the independent entity because of the common need to provide communications over the oceans and emergency alerts. Eventually, Inmarsat was privatized and into a private company that provides telephone and data services to users worldwide.

Space infrastructure and habitats could benefit from a similar model. An entity could be created as a joint project among many nations. It would have a clear mandate to build out prescribed space infrastructure in space, including habitable structures. It could be funded in part by the participating nations, as well as collecting fees from users and stakeholders. Like Inmarsat, we could envision such an entity going private and independent at some point.

The difference with the LDC concept above is that this IGO would be owned initially only by the signatory entities of participating governments. In the Intelsat and Inmarsat cases, this accelerated initial investment and system deployment but created monopolies with little incentive to innovate and lower costs.

Tennessee Valley Authority[2]

Like Inmarsat, the Tennessee Valley Authority (TVA) was established to meet specific needs in rural Tennessee. The TVA is a federally-owned company created in 1933 to control floods, improve navigation, improve the living standards of farmers, produce electrical power along the Tennessee River and its tributaries, and economic development in an area of the US particularly hard hit by the Great Depression. Today, the TVA is the largest public utility in the country, with revenues of more than $11 Billion. The TVA does not receive any funding from the U.S. government, nor does it pay state, local, or federal taxes. The TVA has yet to be privatized.

The formation of a TVA-like company to support space development could help accelerate space industrialization. With a clear mandate to develop space infrastructure and the ability to raise user fees, such an entity could be self-sustaining, providing for ongoing infrastructure development into the indefinite future.

IV Conclusion

A robust space ecosystem is emerging that, sooner than later, will lay the groundwork for large-scale space infrastructure and eventual habitats beyond earth. Whether that is measured in decades or generations, it is not too early to explore the range of financing models required to support such an audacious undertaking. As such, a review of the financing options helps to demystify what it may take to structure such large-scale complex financing mechanisms. If we can show concretely that even seemingly prohibitively high-cost space projects can be successfully capitalized, that may help, in turn, stimulate the preparation of viable business plans for seemingly out-of-reach ventures such as asteroid mining or solar power orbiting stations.

This paper is a culmination of our initial investigation into the financing options. Beyond Earth will continue to identify and explore traditional and novel financing options that can be applied to large-scale space systems.

V Recommendation

The U.S. Department of Commerce (DoC) should undertake a comprehensive study of government-enabled financing mechanisms that could be activated to finance large-scale, in-space infrastructure projects that exceed $10 Billion in total cost. In doing so, the DoC should consider specific project options that have high potential ROI value for both government and private stakeholders. The study should engage government, academia, and industry project financing experts.

1 Sukawaty Andrew. (2019, March 18). Inmarsast Corporate. Enabling Connectivity Business Models. Retrieved from https://www.inmarsat.com/content/ inmarsat/corporate/documents/ (accessed on July 19, 2022)

2 Editor. (2017, August 3). TVA. Tennessee Valley Authority Act Of 1933. Wikipdia. Retrieved from https://en.wikipedia.org/wiki/Tennessee_Valley_Authority (accessed on July 19, 2022)