Outer Frontiers of Banking: Financing Space Explorers, and Safeguarding Terrestrial Finance*

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For decades, governments alone financed launching, operating and returning space objects and humans. Scientific exploration of space propulsion, navigation, communication and life safety advances resulted in commercially viable technologies and business methods. Scientific research and mission goals depended on government space mission priorities and budget appropriation processes. Government funding of exploration still predominates, outspending private sector investments. Commercial satellites are financed based on their terrestrial revenues and the risks of launch and in-service life. Space entrepreneurs are emerging with the wealth and explorer spirit to attract teams to do what governments and space industry contractors have not prioritized or funded: asteroid hunting satellites, space tourism, space freight, lunar and asteroid mining, and habitats on the Moon and Mars. Concurrently, developing countries are launching satellites and missions, diversifying space entrepreneurship. Space finance is an inherent barrier or right.

Space finance is a silent technology enabler or mission continuity risk. Space exploration is a unique setting to reimagine better space and terrestrial finance options and principles based on functional valuation models. Space law was written in the language of foreign policy and security concerns rooted in the Cold War Era. For more private sector financing to explore space, space law and transaction frameworks will need exploration and updating. Finance is essential to advance peaceful discoveries and uses of space assets. If exploring space is to be truly open to all humankind, then options for financing and insuring space explorers and missions must expand accordingly, and inclusively, beyond governments and high net worth entrepreneurs.

This paper reviews relevant treaties and transactional frameworks for financing space operations. Historical context, principles and inspirations are gathered from bank, finance, and market precedents of funding terrestrial exploration and development. The paper summarizes transferable principles and practices of modern asset valuation models, transactional frameworks and strategies for allocating project benefits and mitigating project risk. Based on such principles and precedents, the paper identifies the challenges of, and suggests arrangements for, banking as, and finance of, space-borne assets and activities. A space bank is described to prove that banking in space is viable and improves on terrestrial money flows for fragile regions affected by war, corruption, disaster or breakdown of basic human rights. Weighing historical and modern context and space-based humanitarian and business continuity advantages, the paper concludes by recommending that policymakers elevate space banking, finance and insurance as topics of scientific inquiry, on par with other scientific explorations and technologies, to unleash a reliable future of human exploration of space.

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I. INTRODUCTION

Gaps in financing tomorrow's space economy

Space exploration is entering a new phase of market expansion. Leading this expansion are billionaire explorers attracting startup entrepreneurs and the space mission teams they assemble from industry veterans and new talent, coming together to disrupt previous generations of space industry companies. The new company founders have the capital and seek to grow the market for commercial activities in space. Government space agencies are taking advantage of the new companies' capital to reduce public funding of commercial missions, while privatizing larger portions of mission prototyping risk and investment return.

Privately organized and market financed space exploration is significant. However, gaps and risks in space exploration arise due to the very passion of tying private space missions to the enthusiasm and capacity of space pioneers to fund them privately. A robust "space economy"[1] requires growing the market for linked infrastructure investments, where, for example, investments in launch services to the Moon would be proportional to the Lunar Development activities requiring launch, orbit and return to Earth with lunar minerals or other assets. Founders and angel investors in companies like SpaceX (Elon Musk) and Blue Origin (Jeff Bezos) providing reusable launch services, Virgin Galactic (Sir Richard Branson) providing space tourism, Bigelow Aerospace (Robert Bigelow) for habitats in space, Planetary Resources (Eric Schmidt, Larry Page and Ross Perot, Jr.) mining asteroids and others aim to dominate in offering key assets and services. As leaders of the new space era, the founders are not working off a common view of the space economy or how to collaboratively build it out technically, sequentially or financially.

Project finance, such as to fund satellites, is necessarily focused on underwriting a project's capacity to generate revenues through operations, and to cover risks through adequate guarantees, insurance and pledges of collateral. Project finance can be part of financing a space economy, but again lacks the purpose or panorama view of investing in a space economy portfolio.

Banking and insurance capacity were preconditions to seafaring explorers and mining operators. Likewise, space needs its bankers and insurers to take an holistic view of the space economy in order to attract and invest capital across a broad range of private companies and their interrelated and interdependent projects, project teams, investors and technological achievements. The scale of financing a diversified portfolio of private companies wanting to participate in the next phase of space commercialization requires building on and rethinking commercial and government finance of space today.

Financing space exploration mixes politics, profits, technology, collaboration, laws and dreams

Secured financing of assets involves debtors, creditors, contractual and usage rights pledged as collateral, and a legal framework for establishing and enforcing relationships among the parties and the collateral. The secured creditor's rights to the collateral are prioritized in the debtor's bankruptcy, and a body of international, national and local laws determines which creditors prevail in preserving the value of the assets and ultimately obtaining ownership, rents, revenues and liquidation proceeds from the assets.

Financing satellites and other space objects raises complex issues:

- For design, construction and working capital loans, what law(s) govern the design, construction and launch of the space object?
- For permanent loans on orbiting objects, what law(s) govern the operation, maintenance and physical and cyber-security of the object, its use and the revenue streams produced thereby?
- For space missions spanning years or decades into the future, what law(s) govern assets orbiting Earth, on celestial bodies (such as the Moon, Mars, asteroids, meteorites or other bodies) or in interstellar space, their use, and the revenue streams produced thereby?

The capital market discipline evaluates demand for an infrastructure service, the risk of creating and operating the service and the reasonable return on investments that customer would pay for the service, and then sets an interest rate on debt issued by the company or prices the company's stock appropriately. When venture capital invests in a space technology startup or when governments guarantee demand for launch, satellite telecommunications or other services rendered from or for use in space, they are creating a short-term artificial supply of capital. Industries that rely heavily on such short term capital supports can – as in the satellite industry today[2] – oversupply capacity beyond its economic utility or demand. For a balanced portfolio of capital to support the space economy, all corporate and government space investments need to be seen as an interdependent portfolio serving demand for operating in and exploring space, so that capital is not over- or under-allocated to investments timed to provide the necessary services for subsequent missions and explorers to operate efficiently.

Government Spending cannot assure a Space Economy

The budget sequester of 2013 slashed federal agency budgets by $110 billion, and NASA's budget by $894 million.[3] However, the $17 billion NASA spent for space exploration that year was still more than $13 billion in private investments and debt provided to the space industry over the fifteen-year period 2000 - 2015.[4] Government funding amounts to large investments in space and space related technology, through direct spending, single objective missions such as the Mars rovers, and longer term projects such as the International Space Station. The selection of what to fund however is a constant tug-of-war between Congressional Committee appropriators and the space agencies that spend the funds. Coupled with this political intrigue, government agency executive and program staffs and the space industry companies they support are left in limbo annually as they wait to see the next year's budget authorization. With goals matched to the needs of Congressional Districts vying for job retention and creation from space activities, rather than development of redundant space based capacities, space finance through government programs can overshoot, undershoot or ignore elements of a space economy. This inside the Beltway Game of appropriations can leave innovation and the veteran and new innovators wondering if it is worth even applying for government space funding in light of political uncertainty, program frailty, reporting requirements and bureaucratic red-tape in approval and revision of mission and technology descriptions. None of this self-referential government funding game is new news.[5]

Patchwork of Space Finance ill suits Space Explorers

If the space economy is to be a cohesive growing marketplace, the current public and private financing options are unreliable and their allocation to specific assets hard to analyze. The marketplace needs a publicly accessible clearinghouse of projects and missions that have been funded or seek funding where each past, current and potential investment can be ranked for its quantifiable utility and interdependence with others creating the space economy.

The balance of this paper explores how innovative trends in finance and space can complement each other, how space utility services could be ranked, how a space bank would use such rankings to make investments that build the space economy, and to what extent existing treaties and financial transaction precedents allow for more innovations in space finance..

II. FINANCING ASSETS ENJOYED ON EARTH AND BEYOND

Through domestic and international banking and law and practice, three broad categories of assets can be distinguished for purposes of discussing space finance:

- Assets that have a physical address on Earth, such as buildings and businesses, or a registry maintained on Earth (such as for land, copyrights, patents or other intellectual property), and the rents and revenues they generate (**Earth Assets)**,
- Assets located in orbit around the Earth or in space (such as satellites), and generating revenues primarily enjoyed on Earth (**Earth-bound Asset**s),
- Assets located in space (on the Moon, Mars, an asteroid, meteor or elsewhere), and generating revenues, enjoyed primarily beyond Earth's orbit (**Space-Bound Assets**).

The three categories of assets (**Assets**) interoperate. They share certain characteristics of financeability: Each Asset produces revenues (**Revenues**) directly or through resale or barter of the commodity its use creates (such as mining minerals or water, growing crops, reclaiming and recycling materials for reuse or sharing satellite data and bandwidth). Each Asset is legally defined by the rights (collectively, **Rights**) to (A) own, use, control or improve the Asset, (B) generate, collect and assign its Revenues, (C) enter into absolute and contingent transfers of the Asset, its Revenues and such Rights upon the occurrence of an event, for a period of time, or as exigent circumstances may permit, and (D) exclude others from interfering with or threatening such rights.[6]

III. FINANCE AS DESIGNING AND ENGINEERING THE JOURNEY OF MONEY

Space engineers move objects and humans from Earth's gravity well into other orbits.

Finance engineers - traditionally bankers, financial intermediaries such as private equity and venture capital investors, rating agencies and their regulators - move money. Collectively, they time-shift money, from people or institutions that have it today, to people or institutions that want to build or use Assets today so that generate Revenues and repayments tomorrow. Collectively, financial engineers transform risk, return, financial asset type and duration or maturity until repayment.

Financial engineering is a design science, with constraints for operations determined by regulatory and contextual frameworks of geography (*Where will the money be used?*), timeliness (*For how long will the money be used before repayment?*) and form (*What type of financial contract - debt loan, equity investment, guaranty, option, insurance, contingent assignment - will be used?*) as part of a road map that describes the wiring diagram for the financing to launch capital into a loan or investment, keep it safe there, and return it (plus a reasonable profit based on the risk involved) to its source.

Through asset valuation analysis, asset performance feedback loops, diversification and other hedges, the capital is deployed for a chosen time period across a variety of asset classes, with the mission goal of weathering market forces at reduced risk, while improving returns on the investors' and lenders' portfolio.

Financial engineering is constantly maturing as a science. Finance generates innovations across a range of asset class, geographic and futures markets by creating, combining and synthesizing pooled and derivative forms of debt, equity, guaranty and hedging securities. As financial engineering becomes more reliable through optimizing generally accepted prudent financial risk standardization, pricing and trading models, and as governments promote through regulatory and tax policies a wider diversity of investments by individuals, institutions (such as pension and insurance funds, foundations and university endowments), the velocity of transactions increases, and the costs of originating and trading in securities declines, which in turn drives down the borrower's interest rate and increases the capital available to build, operate and enjoy Assets.

IV. FINTECH, A CATALYST FOR EXPLORING FINANCING SPACE OPERATIONS

With cheap ubiquitous computing in mobile, wearable and desktop devices accessing shared storage, application and data information technology services (commonly called cloud-based services), a new generation of financial engineers and their technologies (**fintech**) has launched, attracting over $22 billion in the two years ending August 2015. Fintech applications on smartphones, personal computers and in core back office processing operations reduce the frictions, delays, inconsistencies and risks of traditional financial services offered by commercial banks, payments and remittances services (such as credit cards, bill payment and money transfer agents), foreign exchange agents and government agencies. **Blockchain**, an extensible digital ledger protocol for currencies and smart contracts, extends the fast changing pace of financial engineering using modern cryptography.[7,8] Fintech is changing the design of banks and financial markets, and giving financial services customers more freedom to assemble mobile phone applications (**apps**) into personalized "virtual banks," much like Apple's iTunes app permits individuals to acquire and play personalized audio, video and book content on demand as virtual jukeboxes in their smartphones.[9] Such customized services reduce financial costs and fees, using algorithms that directly and holistically value borrower assets and credit risk, and offer repayment terms based on the customer's sources of income, earning potential, and quality of life challenges, context and resources.

Relevant examples of fintech would include:

- **SoFi**, a popular marketplace for refinancing student and other consumer loans, is saving borrowers interest expense, while passing on to investors more in interest than banks would pay on regular savings deposits.[10]
- **Kickstarter**, a popular crowd-funding marketplace, permits start-up founders and project designers to share their ideas, attract small equity investments and pre-sell products yet to be made to interested customers.[11]
- **Fundrise**, an emerging crowd-funding marketplace for investing in real estate projects, linking developers of smaller real estate projects and the average investor.[12] (Fundrise).
- **Neighbor.ly**, a platform for investing in the tax-free municipal bonds that build urban infrastructure.[13]

As banking and financial services are accessed online (instead of at the physical bank branch) and as the "banker's judgment" on client creditworthiness and relationship pricing is replaced by algorithms, always-available financial services can be delivered in digital form anywhere human communications exists, even in remote villages.

Given the rapid expansion of fintech and growing interest in commercial space exploration, the growth of fintech in and for space exploration has ripened as a topic worthy of research and innovative prototyping. For example, university research to prototype Cubesat satellites[14] could be extended to developing a "bank in a box" that offers basic banking services and fintech functionality and security aloft.

V. ASSET VALUATION - DETERMINING WHAT GETS FINANCED

Across a large range of financial functions and roles, asset valuation challenges bankers, investors and project operators.

The 2008 Global Financial Crisis was a study in how much valuation of underlying borrower ability to repay and collateral utility matters. In the years of easy credit leading up to the 2008 Crisis, home mortgages and consumer credit lenders and investors misread or ignored the net worth of the borrower and the borrower's income earning capacity as the jobs offered by the local economy rapidly shifted offshore with globalized supply and service chains, and digital business models. Without continued refinancing and purchase of easy credit loans by Wall Street investors, local real estate home prices would have adjusted to homeowners' lower economic prospects and earnings. Instead, investors pumped up real estate prices and the bubble eventually burst realizing that home values in real terms were hyper-inflated, supplying too many homes for purchase at prices that were unaffordable without easy credit.[15]

Commodities, both natural (such as crops and minerals) and human-made (such as energy, waste treatment and wireless data services), are valued based on:

- supply factors (such as growing seasons, weather patterns, energy and water scarcity and cost, labor concerns, and transportation and storage costs),
- demand factors (such as the value of and demand for downstream value-adding supply chain uses, industrial process re-engineering that conserves or substitutes inputs or switches final product flows, and unmet and forecast end user tastes and needs),
- economic recessions and expansions,
- government interventions (adding and removing excise, inspection and usage fees, tax incentives, regulatory shifts and subsidies) and
- multinational tariffs, currency and trade policies.

Valuation of Earth Assets, Earth-bound Assets and Space Assets share these factors, as extended by the distances, remoteness and risks of launching into, operating in and traveling through space.

VI. A NEW ASSET VALUATION LENS

Consider a basic question of valuation: *What accounts for market demand that justifies creating any Asset?* A long-term investor looks beyond today's consumer, commodity, stock or other market pricing to find the *functional value*[16] of the Asset. Spot prices and historical price correlations can be misleading, as too short-term, or as seasonal, or as tied to a legacy economic era, or as easily displaced by newer technology: Polaroid is no longer the instant photography Asset of choice for consumers in the Digital Age, instead they buy GoPro cameras and smart phones (Apple iPhones and Google's Android devices) with cameras that access web services for photo and video sharing.

Imagine a three-layered map of Earth (**3L-Map**)[17] for each geographic area of concern (e.g., a neighborhood, city, political or bioregion, ocean or other area), consisting of:

- **Needs Layer** - What risks for environmental, human, economic or social health, equity or resiliency (**Needs**) persist here?
- **Capacities Layer** - What Assets singly or in combination and business models for using them (**Capacities**) are known or could be incubated to address the known Needs, individually or collectively?
- **Money Layer** - How much is being spent annually or has been allocated to be spent (**Money**) to address the known Needs in isolation or to deliver a pre-determined Capacity or bundle of Capacities?

With a 3L-Map, long-term investors and the peoples affected by the Needs in their territory, can choose Capacities tuned to mitigate Needs, and can tap into the government, bank, foundation, private equity and other sources of capital in the Money Layer that stands ready to (A) invest in Capacities improving quality of life elements in the region of interest, or (B) fund mitigating chosen Needs.

The 3L-Map's granularity scales to prioritize context-aware Asset valuations and credit enhancement. Through a Periodic Table of Quality of Life Elements (such as the adequacy and equity of economic, educational, environmental, health, housing, telecommunications, transportation and other challenges) (**Periodic Table of QoLs**), the functional values at risk (**f-VaRs**)[18] represented by each Need in isolation can be quantified and mitigated.[19,20] Through the Periodic Table, the economic performance and timing of public and private sector investments in Assets that create Capacities to address QoL Elements as Needs can be calculated,[21] leveraging the fact that f-VaRs of certain Elements cluster and interact, resulting in valuable **Adjacencies** that, when available, reduce the investment otherwise incurred in isolation to reduce a given Need's f-VaR. For example, investing in information and telecommunications Capacities permits faster and more targeted monitoring and remediation of environmental concerns, and thereby reduces the f-VaR of environmental quality (a QoL Element of Need) available as an Adjacency for all other elements in the Periodic Table.

Reductions in the f-VaRs of each QoL Element achieved through investments in Assets as optimized clusters of Assets (as Capacities in the 3L-Map) represent Adjacencies that have value and produce Revenues generated through providing risk-mitigation, resiliency or buoyant sustainability to absorb economic, natural or social shocks. The effectiveness of government budgets and the long-term value of private or public-private partnership or joint venture investments in Assets can be quantified: Capacities that reduce QoL f-VaRs translate into reduced municipal, state or federal budgets and safer, more risk resilient and adaptive cities.[22]

VII. VALUING SPACE CONVENIENCE

Building and operating a dynamic space economy could be accelerated by adapting the 3L-Map and f-VaR Asset valuation concepts in order to holistically rank, combine and compare investments in space resident Earth-Bound and Space-Bound Assets (**Space Assets**), vs. terrestrial Earth Assets.

Operating from space carries unique advantages for Earth-bound Assets (where the QoL benefits and f-VaR cash flows are received on Earth), and for Space Assets (where such benefits and cash flows are enjoyed mostly in space). Operating in space offers a convenience and is an economic and scientific necessity in order to build Capacities that address Needs on Earth, on the Moon or permit human exploration of Mars and outer space. For international telecommunications, a satellite network is more convenient, comprehensive and cost-efficient than terrestrial fiber optic cables. For monitoring of agriculture, climate, habitat, defense and urban systems, satellites provide efficient and objective observation platforms from which to see and put in context terrestrial conditions, threats and opportunities for change. For repair and security of space objects, space-based refueling and debris removal may be more convenient and reduce the delays, risk and costs of relaunching and replacing satellites, space station modules and other Assets.[24] For detecting asteroids or meteors likely to intersect Earth's orbit, that cannot be seen from Earth, satellite telescopes tuned to infrared or non-visible wavelengths may be the only viable option for timely, continuous detection.[25]

In the general equilibrium theory of economics,[26] the Unit of Space Convenience (**USC**)[27] for Space Assets would be the cumulative change in marginal cost of the Capacities meeting the space economy's Needs (mapped to the Periodic Table of QoLs), with vs. without the Space Asset(s) being considered for investment as added Capacity. Further research would create a definitive algorithm, but for now the USC is a function of at least the variables described as follows:

Asset is the Space Asset being evaluated,

QoL is a vector of the Quality of Life Elements or Needs for a given region or orbital path in space serving or being serviced by the Asset,

f-VaR is the corresponding functional Value at Risk of the QoL so affected (e.g., how much oxygen, water or telecommunications is needed for space exploration there),

MC-E is the Marginal Cost on Earth of reducing a unit of f-VaR to level A (acceptable f-VaR),

MC-S is the Marginal Cost in Space of reducing a unit of f-VaR to level A (acceptable f-VaR)

For a simple example of USC, consider

- the value of having a special wrench on the International Space Station to fix a leaking fuel tank is $1 million (**f-VaR**)
- the marginal cost of getting the wrench on a rocket that can dock with the Space Station prior to the wrench being needed is $5 million (**MC-E**),
- adding a 3D printer and supplies that can manufacture the wrench on the Space Station costs $2.5 million (**MC-S**), and
- 25 Periodic Table quality of life elements would be assured thereby (**QoLs**).

Take another example: Imagine a country's Agriculture and Health Ministries need to monitor weather patterns (e.g., droughts, floods and heat) that affect crop growing seasons, choice of crops to grow, breed insects and raise pandemic risks to plants and people (all QoLs with f-VaRs to be reduced), and the Ministers have three economic options:[28]

- Option 1: Build, launch and operate the weather satellite service on their own,
- Option 2: Building the monitoring satellite on their own and pay for the launch service to place it in orbit, or
- Option 3: Use an existing weather monitoring service already orbiting its region.

The reduced cost (USC) of moving from Option 1 to Option 2 represents the marginal utility of having a space economy that allows participants to rely on the expertise of a third party launch service. The reduced cost of moving from Option 2 to Option 3 adds more units of space convenience in utilizing the functional value of the Space Asset that already exists. As the space economy grows, Option 3 will become readily demanded as cheaper and more reliable.

The role of space finance is to bridge the time it takes between building a Capacity (such as the weather satellite) and the demand of multiple missions that can use others' and add their Capacity as part of a space economy. By objectifying and funding Capacities as a portfolio of interconnecting Periodic Table of QoL elements for related missions to explore and develop a given region of the Moon, Mars or space, the space finance marketplace would be more assured of demand for any given Space Asset's Capacities.

The tools for valuation of Assets based on Earth that return functional value to Earth, or based in space that return value there ease analysis of the question of how to finance Earth-bound and Space-bound Assets. With the USC, a space economy and its finance marketplace of loans and investments can commoditize the functional value of Space Assets as reducing the mission cost and risk of carrying each QoL's f-VaR into a given region, orbit or trajectory of space. In effect, USC becomes the collateral for banking on Space Assets.

VIII. FINANCING EARTH-BOUND ASSETS TODAY - HOW SATELLITES ARE FINANCED

Satellite Finance - a mature form of space finance

Commercial satellites are part of a robust and mature $203 billion[29] private market for Earth-Bound Asset finance. While governments finance satellites for civilian and military/intelligence Capacities, the strength of the commercial satellite marketplace is growing, especially as small Cubesat satellites can be cheaply and rapidly designed, built, launched as payloads, and operated, until their orbits decay.[30]

Anatomy of a Satellite Finance Deal

The typical satellite project involves soft costs (design, insurance, legal, finance, launch licensing and space object registration), hard costs (engineering, building, testing and transporting the satellite to the launch site), and entails pre-launch and post-launch liabilities and risks.

Financing of commercial satellites leverages equity and adds debt. Equity is provided by stock market, private equity and management investors to (a) capitalize the satellite operator and satellite fabricator, (b) recruit a core management and technical team, (c) build a ground station and (d) market and build devices and software interfaces to access the services being supplied by the satellite. Project and working capital debt in the nature of short- or longer-term receivables finance can be secured or unsecured. The debt is repayable based on the timing, amounts and credit quality of cash flows generated by selling the information services provided by the satellite once in orbit. An AT&T or DirectTV satellite would pledge as loan collateral its monthly consumer subscriber and advertising revenues derived from satellite broadcast and broadband services. A government contractor building a satellite or operating services for the government would pledge its government payments.

The operational health of a satellite is tied to the financial health of its operator. Investors, governments, customers and industry analysts continually monitor satellite industry revenues and capacity.[31,32,33] Financial ratios permit lenders and investors to gauge the financial health of a satellite company as of the end of a calendar quarter or year, accounting for historic decisions. Common ratios include debt to assets (D/A), debt to equity (D/Eq), current assets (cash, U.S. treasuries and assets easily converted to cash) to current liabilities (debt service, rent, payroll and other payments coming due in the normal course of business)(CA/CL), earnings before interest, taxes and depreciation and amortization (EBITDA) to debt service and interest (Eb/I) and debt as a multiple of EBITDA (D/Eb).

Satellite Cash Flows as Collateral

Given the cost to build, launch and operate a commercial satellite, its financeable value largely depends on the willingness of Earth-based individuals, businesses and institutions to pay for services provided by the satellite, thus generating its cash flows. The cash flows of current satellites come from and stay on Earth.[34] Because information is increasingly a commodity (one megabyte of data is the same size as the next), satellites capable of moving more data faster and safer will naturally displace older satellites whose data transmission rates were smaller, slower or more vulnerable to cyber attack. Thus, the commercial lifespan of a satellite engineered to remain in orbit for fifteen years may become obsolete after ten years useful life, as satellite communications market demand, premium pricing and technical capacity evolves.

Role of Export Credit Finance

Government export credit agencies (ECAs) play a large role in bolstering the international competition for contracts to build and operate satellites. The Export-Import Bank (Ex-Im Bank) in the United States, Coface in France, Export Development Canada, Japan Bank for International Cooperation, the U.K. Export Finance, the Export Insurance Agency of Russia, India's Space Research Organization (ISRO) and its marketing arm Antrix, and other government-subsidized export credit guarantors and lenders provide significant liquidity and capacity to the satellite industry.[35] The satellite industry's reliance on ECA-backed financing adds political risk and operational delays to the business model and supply chain partnerships of companies that build and operate satellites.[36]

Mission Risk of Over-Reliance on Government or Private Sector Finance

On Earth, the consequence of a delayed launch may result in substitution of increasingly abundant alternative services, given the ease of launch and redundancy of Earth-bound satellite sensor and telecommunications networks today. However, for people, businesses and future colonies already in or operating in space, or with missions relying on upgrading Earth-bound or Space-bound Assets, government or market delays or shutdowns in access to space finance can threaten human life and destroy the nested business models of future projects and lean startup companies managing them.[37] Redundancy in financing space activities is needed, alongside the diversity of government, private and public-private space finance.

No space traveler or mission can afford to risk the failure to launch or maintain a key Space Asset. Stated differently, when every space explorer or mission must rely solely on their own spacecraft or operating base for supplies and logistical support, without the economy of reliable Space Assets reliably financed (the **space economy**), the mission cost of over-engineering such explorer's self-reliance inflates the cost and risk of pioneering scientific missions, and leaves exploration of space open only to wealthy governments, corporations and individuals.

IX. DESIGNING A SPACE BANK

As has been shown, financial risk mitigation and asset valuation models can be explored to assure that Space Assets get financed on a timely and regular basis, independent of government, foundation or private investor whims, fads and oscillations.

An experimental space bank (**GoodBank™**)[38] would provide the platform for exploring the design and engineering of finance, as an integral component for commercial and scientific exploration of space. Through a space bank, new forms of Space Assets, the f-VaRs for QoL Elements that they service, and the holistic marketplace for more diverse space explorations can be readily attempted and refined.

A space bank could be multipurpose (for Earth-based, Earth-bound and Space-bound Asset transactions) and could leverage and inspire fintech algorithms, user experience designs and cyber-threat and operational resilience for terrestrial and space banking purposes.

The value of a space bank is twofold: The bank collects and supplies capital to be loaned and invested consistent with its purpose of growing the space economy. To operationalize that purpose, the bank would develop and improve on an underwriting model for consistently determining how a given project offers the space economy services that reduce f-VaRs, functional values at risk, which thereby makes other space activities safer or more effective, by lowering the need for and cost of redundant systems for each mission.

X. HOW A SPACE BANK ADDS FINANCING OPTIONS FOR SPACE ASSETS

Four fact patterns illustrate how a space bank would operate, and why going beyond terrestrial banks and finance will prove worthwhile.

Example 1: Earth-Bound Resiliency: Humanitarian and Disaster Response Banking

An earthquake or natural disaster wipes out ground-based Internet and telecommunication lines, electric power and the familiar terrain of city streets and shops. A humanitarian crisis of homelessness, displaced families and years of rebuilding small farms, village fishing and small businesses ensues. In countries and regions experiencing civil or sectarian violence, civil society activists, health care workers and officials striving to create a governable civilian city or nation state fear that being identified through official bank payment networks exposes them and their organizations to being targeted for extortion, elimination or incarceration. Forty percent (40%) of humankind (2 billion people) on Earth lacks a basic bank account or convenient financial services for handling money safely, free of agent fees, moneylender high interest on borrowed funds and crippling debt.[39,40] For people in such economic and fragile settings and circumstances, sidestepping the corruption and corrupting influence of official and unofficial processes for receiving and paying money becomes nearly as dangerous as succumbing to it.

A space bank would permit instant access to funds in accounts safeguarded outside of the fragile, disaster or conflict zone. Rather than carrying and storing cash, residents and foreign aid specialists could use the space bank to transact without fear of government surveillance or extortionate threat or demand. Moreover, for auditing and financial management purposes, the traceability of foreign aid contributions and grants for disaster and humanitarian response could be created and preserved in space, and generated with digital QoL f-VaR tags as transactions occur, rather then after the incident, when memories fade as to how funds were spent, by whom, where and for what purpose.

Blockchain and crypto-currency technologies could provide the payments, remittances, grants, investment, and loan transaction ledger services. Computational contracts (also called smart contracts) could provide improved documentation of the transactions, how they were authorized and what performance covenants exist to be enforced.[41] But they require uninterrupted Internet access that is resilient to cyber attacks and unfriendly government or extremist eavesdropping or misuse.

In order to provide as continuity of prudent banking services – compliant with anti-money laundering (AML), know-your-customer (KYC), regulatory capital, foreign exchange, supply chain payables, treasury and prudential management of time-critical international banking considerations – a space bank and a culture of bankers supporting it could be a crucial resource for humanitarian and disaster response teams deployed to the affected city or region using fintech.[42] A space bank can automate authentication of the funds being used to mitigate ground conditions observable from space, such as by confirming reforestation, replanting farms, cleaning up debris from tsunami, hurricane or other weather event, and building of housing and city streets. Humanitarian and disaster response banking scenarios invoke the case for operating a space bank to anticipate the transactions needed to see and speed restoring quality of life in vulnerable regions - regions increasingly at risk without continuous foreign investment and impacts transparency. As banks, financial institutions and their regulators ponder business continuity risk, resiliency and recovery scenarios, a space bank would augment terrestrial offsite facilities, as a layer of protection beyond offsite.

<u>Example 2: Space-Based Resiliency: Financing Repair, Salvage and Re-Use of Space Objects</u>

International Guidelines on Space Debris Mitigation contemplate reentry destruction as the method for reducing the debris caused by space objects' end-of-life.[43] Given the costs and risks of launching spacecraft into orbit, the recommendation that disabled or end-of-life Space Assets be destroyed seems an uneconomic policy. Many assets built in advanced economies to serve higher income and larger corporate customers can be engineered, rebuilt and maintained to be reused by local entrepreneurs and their small businesses in Developing Economies. Programs for salvage and reuse of clothing, cellphones, bicycles, automobiles, farm equipment and similar assets prove the business model of recycling to lower income groups, a global reverse supply chain known as down-cycling. Space Assets that have run out of fuel or have a torn solar array or defective battery, or whose navigation computer needs replacement could be repurposed, subject to the costs, benefits and required approvals of doing so.[44]

<u>Example 3: Space Exploration where Finance Links Space Assets – The Story of Three Rovers</u>

Imagine on the surface of the Moon, or Mars, or one of the Martian moons there are three rovers. The first has sensors to prospect for sources of water-ice buried beneath regolith. The second rover has counter weights to excavate vast amounts of regolith. And the third rover has a heated tank and landscape driving system so that it may transport regolith for processing, storage and use. Combining the three rovers' functions would generate economic value through search, mining and processing of water – a useful material for rocket fuel, energy, and human habitation.

Individually these rovers and their enabling technologies and capabilities would not exist, however, without a fourth mechanism contractually linking their functions and pledging that contract – in effect a water supply contract – to finance the construction and operation of the rovers and the regolith processing and water supply business. A space bank would understand the commodity needs of present and future missions based on the 3L-Map of a space economy activities regionally. The space bank would take advantage of fintech advancements such as computable contracts on the blockchain to write financial instruments or options contracts that align the value chain of the three rovers. Such funding agreements could be used to finance the development of commodity and service markets beyond water, while also reducing the overall mission risk of delivering highly valuable commodities and services.

Instead of hosting multiple, tangential functions on a single rover as a single point of failure throughout the launch, transfer, landing, and operations phases; the three rovers will distribute the technical risk and reduce mission risk. From operating the different rovers concurrently, to funding smaller and more agile enterprises that focus on the specific technologies, to reducing integration and testing needs across the three rovers – benefits exist at multiple levels. Furthermore, the entire mission no longer relies on a single launch of a rover that weighs more and takes up more volume to accomplish all of the tasks on its own. These reduced risks translate to lower costs for financing and an increased utilization of Space-Assets as supply chains for subsequent rovers and missions.

Example 4: Space Exploration: Opening and Democratizing Finance for All Scientific and Humanitarian Missions

An essential feature of the Outer Space Treaty of 1967 is that space should be open for exploration by all humankind, and that no nation may claim sovereign rights to any object in space.[45] Colonial eras in the exploration of North America, Africa, the Middle East and Asia provide powerful historical lessons of human, economic, environmental and governmental instability that succeeding generations experience as regional and global threats. The Outer Space Treaty rejected colonization of outer space. As a *de facto* matter, however, exporting Earth's Colonial Era to outer space is a certainty if the financial means to explore space remains in the hands of few nations or individuals.

During and in the several decades after the Cold War, the United States and the Union of Soviet Socialist Republics vied for space supremacy, an era of civilian and military investment, public relations and scientific discovery known as the Space Race. Today, high net worth (**HNW**) individuals are investing in space launch, tourism and resource mining exploration, alongside smaller governments whose satellite and scientific prowess is being carried aloft on government and commercial spacecraft.[46] Examples of today's HNW space explorers include:

- SpaceX's Elon Musk,[47,48,49]
- Blue Origin's Amazon CEO Jeff Bezos,[50]
- Peter Diamandis' X Prize and asteroid mining Planetary Resources,[51]
- Paul Allen's Stratolaunch,[52]
- Robert Bigelow's inflatable space habitats,[53]
- Sergey Brin and Larry Page individually, and their Google investments in SpaceX, Google's X Prize and more, and
- Networks of HNW space "angel" investors[54]

If space exploration is to be and remain truly open to all humankind, then space finance must be opened to all. Consider the Developing Countries, who are now adding universal education and healthcare, experiencing economic growth and greater political stability, and are attracting business investment, creating jobs and striving for stable monetary and fiscal policies, Such countries' citizens and businesses require reliable financing of their peaceful uses and exploration of space.

Space finance is an ingredient as vital to space exploration as the sciences of space object launch, propulsion and navigation, the fabrication of human habitat for working in space, and the Internet for communications in space.

Space Assets that provide quality of life functions to others on economically reasonable terms that are engineered to support multiple missions and use cases create a space economy that reduces the mission cost, risk and financing burden of future or co-dependent missions. A space bank to finance such sharable Space Assets opens space exploration to more of humankind at reasonable cost and risk.

XI. HOW SPACE TREATIES, LAW AND COMMERCIALIZATION PRACTICES IMPACT SPACE FINANCE

Basic Space Treaties did not Envision Commercialization of Space Finance

The United Nations treaties on outer space that were adopted in the 1960s and 1970s still provide the most important legal framework for the conduct of outer space activities.[55] At that time, space activities were almost exclusively conducted by the small number of governments and international organizations that controlled and provided the necessary resources, as the Cold War subsided, when superpowers' government budgets financed space technology and exploration. The legal framework for outer space activities to a large extent is a body of public international law that is focused on the relationship between states and international organizations.[56] Non-governmental entities are addressed insofar as states have the obligation to "authorize and continuously supervise" their activities in outer space for which the states are 'internationally responsible'. (Outer Space Treaty, Article VI.) States are liable for damage caused by space objects, including private ones, for which they are considered the "launching state." (Liability Convention, Articles II and III). Under the UN space treaties, registration of space objects is mandated. (Registration Convention, Article II). The registration in a national registry determines which state has the right to exercise jurisdiction and control over the space object. (Outer Space Treaty, Article VIII.) This state-centric legal framework bounds financing of commercial space activities.[57]

Legal Issues in Asset Based Finance of Commercial Space Activities

Commercial space activities, just as other commercial activities, are governed by the respective states' national laws, most importantly contract, property, tort, creditors rights bankruptcy, insolvency, reorganization and other laws. By their nature, space activities pose issues of cross-border jurisdiction. As has been well observed: " 'Space law' is akin to 'family law' or 'environmental law' where many different laws are denoted by reference to the material with which they deal rather than being derived from the pure rational development of a single legal theory."[58]

Space assets are high-value mobile equipment whose construction, use and logistical purpose move them and the enjoyment of their value from one place to another, much like cargo-carrying trains, aircraft and ocean-going vessels. Financing movable assets is a particular challenge in the absence of global uniformity of national laws for cross-border asset based lending.[59] Presently, different legal regimes allow for (and can entangle) a variety of financing methods.[60] Imagine the complex jurisdictional issues of a bankruptcy, insolvency or reorganization proceeding, where a borrower granted various lenders security interests in functionally-connected space assets as collateral, and each lender registered their interest in multiple states.[61] The opportunities for choice of law, conflict of law, multi-jurisdictional litigation and ambiguity make lending to the satellite project and other Space Assets "bespoke" tailoring, raising the cost, risk and delays such that only the most expensive projects are worth the effort, relegating the balance of Space Assets to be financed from government or private investment sources.[62] Differences from country to country are relevant at three stages in the life of a security interest in an asset: (a) at the creation of the security interest (e.g., whether movable assets can be used as a collateral at all), (b) the perfection of the security interest (e.g., to give public notice of the security interest so to bind third parties) and (c) the enforcement of the security interest (e.g., to take possession of the asset, to sell it or to appoint a receiver).[63]

Conflict of law rules resolve commercial disputes where more than one national law could be applied. In the case of property law, the rule of *lex rei sitae* is internationally accepted. This means that the law of the state applies in which the property is situated. Enforcement of a creditor's security interest is particularly difficult for space assets. Taking physical, commercial and technical control of a satellite requires success in navigating the legal rules for appointing a receiver and selling the space asset – rules that are increasingly complex and uncertain. For example, under Article II of the Outer Space Treaty, outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. While the satellite is 'situated' under no jurisdiction, Article VIII of the Outer Space Treaty would apply the law of the state of registry of the space object. However, this might not be the state in which the borrower or the lender reside, or in which the security interest in the movable asset is registered.

The resulting legal complexity and uncertainty make asset based financing of space projects hard to standardize, thus increasing financing costs amongst fewer sophisticated investors and lenders. For good or bad, modern financial markets thrive on scrivening the unique of a credit card bill or home loan into standardized financial promissory note and security arrangements on terms that are generally known to investors to be enforceable by lenders, and then pooling those instruments or derivatives of them.[64] Such commodification of financial promises is difficult when bespoke public-private partnerships, joint ventures or other tailored financial solutions are the norm, as they are in space finance.

Because the basis for lending on the space asset as collateral is bespoke, complex and uncertain, financing for space currently depends largely on the creditworthiness of the borrower, rather than a mix of credit-backed and asset-backed financing.[65] This situation disadvantages start-up companies globally and entities in developing countries that lack a track record or creditworthy guarantor. They might receive government grants for academic or scientific research and development at the outset for early phases of the work, but find it hard to raise commercial project and operations financing from the private sector. Such bridge and pre-commercialization stage finance hurdles create constant cash flow liquidity shortages that frustrate building out technical teams and subcontractor arrangements. As government space budgets (inflation adjusted as a percent of national gross domestic product) are decreasing and governments spend on economic, environmental and social crises in the moment, new and innovative space projects will fail due to the inconsistency of financial support.

<u>The Cape Town Convention and the Space Assets Protocol</u>

The Cape Town Convention of 2001[66] was developed to overcome the problem of obtaining secure and readily enforceable rights in aircraft objects, railway rolling stock and space assets, which by their nature have no fixed location, and in the case of space assets are not on Earth at all.[67] The Convention's goal is to facilitate the financing of the acquisition and use of mobile equipment of high value in an efficient manner and to establish clear rules to govern asset-based financing and leasing for this purpose.[68] The Convention established a harmonizing framework for modernizing the application of how each state's legal system creates, prioritizes and enforces security and title reservation rights in mobile assets – rights that if left uncoordinated serve to frustrate productive lending and investment, and "inhibit the extension of finance, particularly to developing countries, and to increase borrowing costs."[69]

The Convention is unique due to its unprecedented use of supplementary protocols.[70] It is a "framework" Convention that only operates through its envisaged protocols – one on aircraft equipment, another on railway rolling stock and a third on space assets. The Convention lays down the fundamental concepts and principles, and the protocols elaborate on the specific rules for the respective industry.

The Aircraft Protocol[71] was ready for signature at the same time as the Convention in Cape Town (2001) and entered into force, together with it, in 2006.[72] The other two protocols for rail and space assets were left to be drafted and negotiated by future working groups and diplomatic conferences.

The Rail Protocol was adopted in Luxembourg on February 23, 2007, but has not entered into force because its contemplated International Registry of rail assets has not become operational.[73]

The Space Assets Protocol was adopted in Berlin in 2012[74] after several years of expert meetings facilitated by UNIDROIT.[75] However, due to the withdrawal of support by the space industry and several space faring nations, the final text has not found broad acceptance. Only four states have signed the Space Assets Protocol, and no state has ratified it so that it has not entered into force yet.

As a unifying legal framework to improve financeability, the Convention, together with its Protocols, introduces new concepts and procedures to achieve more security and certainty for asset-based finance of high value mobile equipment: (a) the creation of "international interests," (b) the establishment of an "international registry" and (c) the introduction of default remedies for creditors to more effectively enforce their claims.

International Interests

The concept of an "international interest" is the cornerstone of the Cape Town Convention.[76] It is constituted by a written agreement creating or providing for the interest, e.g., a security agreement, a title reservation agreement, or a leasing agreement.[77] If it relates to a space asset, it must be an "identifiable" space asset, in that it contains a description of a space asset by item, by type, a statement that the agreement covers all present and future space assets or a statement that the agreement covers all present and future space assets except for specified items or types.[78] The Space Assets Protocol does not refer to the term "space object" – as that term is used in the UN space treaties. Rather, the scope of the Space Assets Protocol would extend to "any man-made uniquely identifiable asset in space or designed to be launched into space" comprising not only of "spacecraft, such as a satellite, space station, space module," but also "a payload (whether telecommunications, navigation, observation, scientific or otherwise) in respect of which a separate registration may be effected in accordance with the regulations" or "a part of a spacecraft or payload such as a transponder, in respect of which a separate registration may be effected in accordance with the regulations."[79]

International Registry

According to the Cape Town Convention, an "International Registry shall be established for registrations of (a) international interests, prospective international interests and registrable non-consensual rights and interests, (b) assignments and prospective assignments of international interests, (c) acquisitions of international interests by legal or contractual subrogations under the applicable law, (d) notices of national interests, and (e) subordinations of interests referred to in any of the preceding sub-paragraphs."[80] While the registry of the Aircraft Protocol has been established and is successfully operating,[81] the Space Assets Protocol has left the establishment of the registry open. It is still under discussion, where the registry should be situated and whether it should be affiliated with an existing organization or secretariat, such as the United Nations International Telecommunications Union (ITU).

Default Remedies

The Cape Town Convention provides for three different default remedies of the creditor: (a) take possession or control of any object charged to it, (b) sell or grant a lease of any such object, and (c) collect or receive any income or profits arising from the management or use of any such object.[82] The Space Assets Protocol modifies these remedies and adds two alternatives:[83] (a) the creditor can be granted possession of or control over the space asset within a specific period of time and retain these rights until the debtor has remedied the default, or (b) the court of the primary insolvency may take the decision on the terms of the remedy available to the creditor in accordance with applicable national law.[84] This change in remedies reflects the nature of space assets that go beyond other valuable mobile equipment, such as the physical qualities of assets orbiting in outer space, and interaction with rights and obligations of states under the UN space treaties.[85]

Lack of Support and Ratifications of the Space Assets Protocol

The Space Assets Protocol has not enjoyed the support of the space industry or important space faring nations that initially favored its organizers.[86] This came as a surprise, as the Protocol would reduce the complexity and uncertainty of space asset financing, create greater security and simplicity for financial transactions and thereby, boost private market capital flowing into commercial space activities. During negotiations, the initial supporters vanished and even turned into a opponents of the Protocol. Some state delegations expressed their concern that the Protocol would in some ways contradict their rights and obligations under the UN Space Treaties, as regards their authority to issue licenses, approvals, permits or authorizations for the launch or operation of space assets.[87] States were concerned how to strike the most appropriate balance between, on the one hand, the interests of a creditor seeking to exercise remedies against a space asset performing a "public" service in the event of its debtor's default, and, on the other, those of the state wanting to ensure continuity of the performance of the particular "public" service notwithstanding the default.[88] Just before the Berlin diplomatic conference, major satellite companies issued a joint letter opposing the Space Protocol.[89] Their opposition was founded on their belief that banks and special investors did not value security interest in space assets adequately and concluded that the capital markets presented a better source of financing.

Towards Unifying Principles for Space Finance

Today's patchwork of international space treaty provisions, and reliance on multi-national lending laws and practices will be difficult to project out to space, to colonies on the moon, Mars or elsewhere. While the lineage and pedigree of the principles of Law of the Sea provide precedent, the lack of a compact on space finance will slow, reduce and add risk to space finance.

In order to evolve comprehensive, modern finance principles for Space Assets (**Space Finance Principles**), innovations that provide and improve an open, transparent and fair market for pricing and trading Space Assets can be encouraged, including holistically measuring the QoL benefits of Space Assets, so that mission synergies can be reliably planned and leveraged into a healthy space economy.

XII. SPACE BANKING OF SPACE ASSETS IN THE ABSENCE OF CONSENSUS ON SPACE FINANCE PRINCIPLES

Absent full ratification and implementation of the Space Assets Protocol or another universal regime of Space Finance Principles, property rights in Space Assets generally may be seen as purely functional, lasting as long and accruing to the extent used or imminently and reasonably useful for scientific, commercial or beneficial purposes.[90]

This functional definition of property rights in space mirrors rights to terrestrial intellectual and real property: For example, regarding intangible assets, in the United States under federal law, copyrights last for 70 years beyond the author's lifetime, trademarks last for 10 years, and patents last for 20 years;[91] and regarding tangible assets, in California by state law, riparian rights to divert and use water flowing from rivers and streams are regulated as the private appropriation of a publicly-owned asset,[92] and real property easements that the holder can lose through abandonment, non-use or misuse.[93]

The functional property right to make use of Space Assets, as opposed to the right to own an orbit or a geographic location in outer space or a resource naturally there, is not a barrier to financing. Rather, the required functionality test for the property right enhances financing Space Assets that will be used, holistically, and the orbits, satellites, ground stations or other apparatus installed to enable and enjoy such practical use. Absent a "value in use" property rights regime, outer space exploration would degenerate into a high conflict whack-a-mole game of land grabs, inviting speculation in asteroid, planetary and orbital claims by claimants that have little intention or desire to develop the underlying resource as a Space Asset that can support further exploration or the science of space exploration as part of a space economy.

The functional property definition of Space Assets is well suited to the Periodic Table's functional Value at Risk (f-VaR) analysis of how development of the Asset would reduce risk on Earth or in outer space.

A prudent space banker would deploy funds from depositors through loans and investments in Space

Assets, and missions and projects maturing Space Assets, when creating or developing such Assets reduces the cost and risk, and improves the value and likelihood of success, of other Assets, on Earth and in outer space. This is the classic economic role of bankers and intermediaries serving in that role. The demand for the Quality of Life Elements provided by the Space Asset increases proportionate to the number of parties operating in space, each of whom otherwise would have to budget for missions that bring the entirety of Periodic Table of Quality of Life Elements with them on each mission. The cost of each mission declines as the shared Space Asset infrastructure available for exchange, use and reuse rises, infrastructure in part financed by space bankers.

Fintech advances include using the Blockchain for post-trade clearing of transactions, foreign currency exchange, smart contracts that transfer Revenues and represent the loan agreements for financing Assets, mobile banking apps, and autonomous artificial intelligence (AI) that credit scores borrowers and allocate investments in wealth management portfolios. Space banking would extend fintech through apps using distributed ledgers of trust to track parties generating value through Space Asset design, construction, operation and collaboration. As prototypical space banks explore Space Finance Principles that can be open as standards for other banks and financial market participants, the number, diversity and market capitalization of Space Assets and their missions will expand.

XIII. CONCLUSION

In 2016, financial technologies (fintech) are massively challenging and changing traditional banking. Financing should change as quickly for space explorers to build the Space Assets needed for a dependably safe, inclusive and far reaching space economy. Using others' Space Assets generates functional values for space explorers, who get to rely on the quality of life benefits of having telecommunications, logistics, water, construction materials, fuel, shelter and other benefits of accessible assets, far cheaper than generating the entire Periodic Table of quality of life elements on each mission and each mission's budget. Using a common and evolving underwriting and investment model for financing Space Assets that supply services and reduce risks in various quality of life concerns reflected in the Periodic Table will grow a private financial market for Space Assets as part of the space economy. By building on the success of satellite financing, new financial innovations, such as a space bank, can reduce costs so that all humankind can obtain financing for space exploration and use, on fair and reasonable terms.

Development of space finance, through a space bank, investor networks and other means, would inform efforts to adopt unifying Space Finance Principles. Through financial underwriting and investment models researched and piloted in a space bank, a space economy would grow faster, assuring that Space Assets can provide the functional value of the Periodic Table's full range of QoL services, in orbits and at accessible distances likely to be traversed by space explorers. In time, Space Treaties would be amended to further enable and recognize new forms of space finance. This paper proposed calculating the space convenience of Space Assets, an objective benefits stream that would provide the revenues as collateral that bankers and investors need as sources of repayment. If space finance grows as a domain of space research and development, space exploration will be truly opened to all humankind.

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[1] "Space economy" as used herein refers to the economy that builds, operates, exchanges and finances Assets that improve use of the functional value of space exploration, discovery and commercialization. This definition upgrades the traditional definition of the "space economy" as a nominal percentage of the gross domestic product of a national economy generated through investments in facilities and employment on Earth to build and operate Assets involved in space activities. Compare Griffin, M. D. (2007, September 17). *The Space Economy NASA 50th Anniversary Lecture Series Michael D. Griffin*. Retrieved July 29, 2015, from NASA.gov: http://www.nasa.gov/pdf/189537main_mg_space_economy_20070917.pdf, Organization for Economic Cooperation and Development (OECD). (2014, November). *The Space Economy at a Glance 2014*. Retrieved September 17, 2015, from OECD.org: http://dx.doi.org/10.1787/9789264217294-en and NASA Office of the Chief Technologist. (2014). *Emerging Space Report: The Evolving Landscape of 21st Century American Spaceflight*. Retrieved September 17, 2015, from http://images.spaceref.com/docs/2014/Emerging_Space_Report.pdf

[2] de Selding, Peter. (2015, September 14). *Investors Grow Bearish on Fixed Satellite Services* Retrieved June 30, 2016, from SpaceNews: http://spacenews.com/investors-grow-bearish-on-fixed-satellite-services/ In May 2016, Moody's corporate investment rating for Intelsat remained at Caa1 defined as "highly speculative, of poor standing, subject to very high default risk." de Selding, Peter (2016, May 18) *Moody's says Intelsat may need to downsize satellite fleet*. Retrieved June 30, 2016 from SpaceNews: http://spacenews.com/moodys-leaves-intelsat-rating-unchanged-evokes-possible-sale-of-part-of-fleet/#sthash.ek4zyZPy.dpuf; de Selding, Peter B. (2016, June 30) *Intelsat announces private placement to repurchase debt*

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[6] The topic of asset-based lending for Earth Assets is fundamental to, and beyond, the scope of this Article, and is admirably covered in textbooks used by asset-based lenders, their lawyers and market regulators. See, Udell, G. F. (2004). *Asset-Based Finance: Proven Disciplines for Prudent Lending*. New York, NY: Commercial Finance Association.

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[27] Any discussion of space finance necessitates shedding parochial concepts and allegiances. The authors humbly apologize to colleagues at the University of Southern California (a different USC) for the mere coincidence of an acronym.

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References throughout this paper to a *space bank* in the singular should be read to evolve the experimental space bank into a network of *space banks* operating as an international research and learning cooperative, iterating and sharing lessons learned towards consistent valuation, risk and operating principles so as to grow a portfolio of Space Assets and the economics of space convenience they provide.

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