CONFIDENTIAL MATERIALS – DO NOT COPY, CITE, POST-ONLINE OR OTHERWISE USE WITHOUT PERMISSION

Space Commodities Exchange

Financial infrastructure to grow a sustainable space economy

Bruce Cahan, JD
CEO, Urban Logic, a NY nonprofit
Lecturer, Stanford Management Science & Engineering

Presented June 11, 2019
Space Resources Roundtable

COLORADO SCHOOL OF MINES EARTH • ENERGY • ENVIRONMENT

Bruce Cahan, CEO Urban Logic, Inc.

Stanford University Lecturer, School of Engineering - Management Science & Engineering
Co-founder, Stanford Sustainable Banking Initiative

Banking and Finance Innovator
Through his nonprofit Urban Logic, Bruce conceived of the GIS utility for NYC and found $100M to fund the City's base map. Bruce is creating GoodBank™(IO) as an independent teaching hospital bank to grow a new banker culture. As a Lecturer in the School of Engineering, mediaX Distinguished Scholar and as an active participant in the Center for Legal Informatics (CodeX), Bruce is reimagining banking, finance and law.

Bruce's reports for the UK's Technology Strategy Board (KTN-FS) and other government and industry groups, and his input into bank regulatory policy and practice are sought after insights. Bruce curated TEDxNewWallStreet, and similar gatherings to reimagine banks and banking.

Bio
Recovering Wall Street lawyer, Hong Kong merchant banker, advised US, NY State & other governments on finance and geospatial innovations, 9/11 emergency responder, Ashoka social entrepreneur & father of 25 year old twin sons…

JD Temple University School of Law **Bar Admissions** CA, NY & PA
BS Economics & International Business Wharton School University of Pennsylvania

Google Profile http://www.google.com/profiles/brucebcahan

My range is passionately wide

Teaching to attract a new cohort of Sustainable Bankers and Investment Professionals:
- Sustainable Banking (CEE 244A 2012 – 2016)
- Ethics of Finance & Financial Engineering (MS&E 148 2016 - 2018)
- Investing on the Buy Side of Wall Street (MS&E 449 2016 - 2019)

Research to reward Sustainable Finance customers' impacts:
- **Banking, Finance & Commodities Market Innovations that would grow the Space Economy**
- Valuing what matters: Periodic Table of Quality of Life
- Three-Layered Map of the World so indigenous peoples use money to match others' capacities to their needs
- Real Estate design, construction, use, insurance and financing decisions on the blockchain (RE-OS)
- Parametric Insurance via computational/smart contracts of insurance to respond to disasters & humanitarian crises
- Migration Storytelling Project to go back 5,000 years and see common journeys
- Faith-based traditions of sustainable finance, and how to implement them today

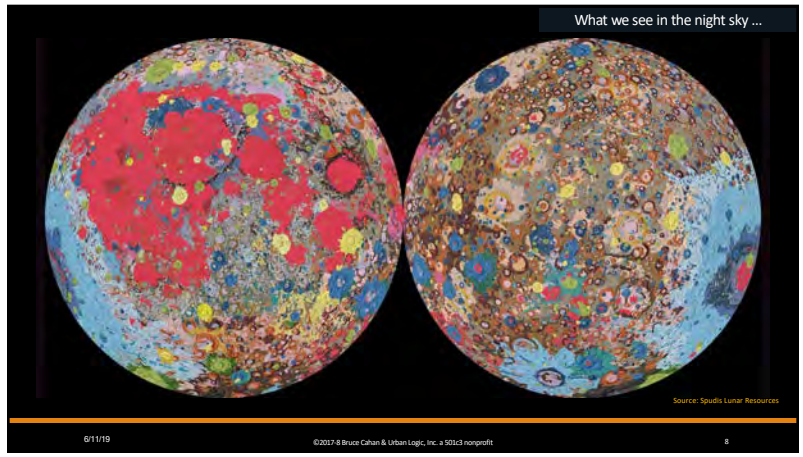
GoodBank™(io) as an independent teaching hospital lab for sustainable bankers (Urban Logic)

Abstract

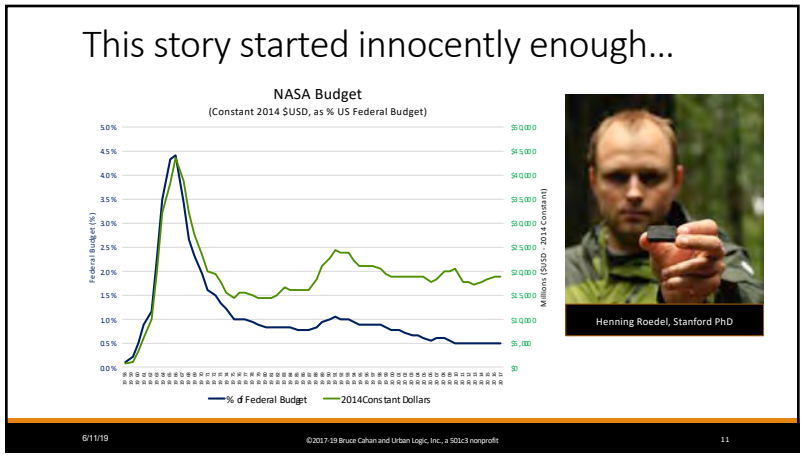
- Once we mine space minerals, how will we trade them?
- Before we mine space minerals, how will the risks be packaged and evenly born by investors, customers, suppliers and their insurers?
- To support continuous space mining operations, how will supply chains evolve to improve the efficiency and profitability of mining companies and their technological evolution?
- In short, what cooperation and competition mechanisms will be put in place to secure a healthy space economy?

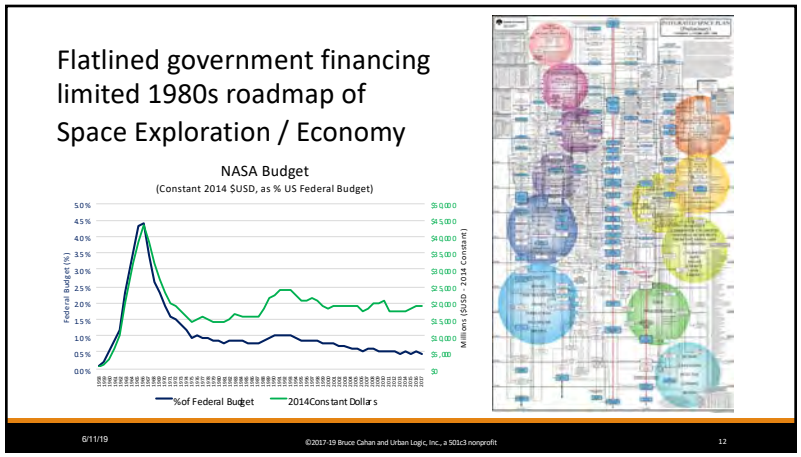
6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 6

6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 7



6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 8



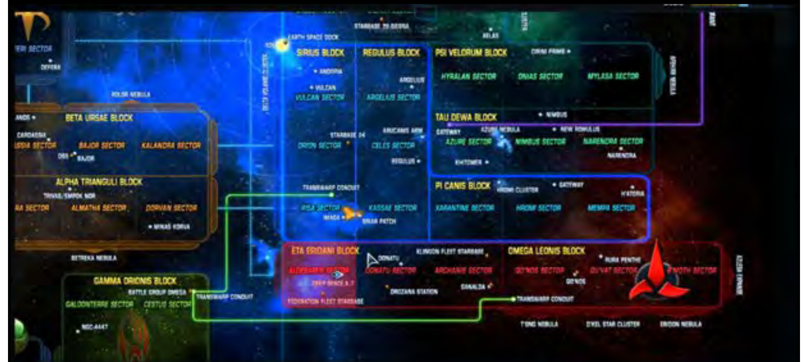


CONFIDENTIAL MATERIALS – DO NOT COPY, CITE, POST-ONLINE OR OTHERWISE USE WITHOUT PERMISSION

2 papers: The Outer Frontiers of Banking in Space

6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 13

Gamifying the Space Economy



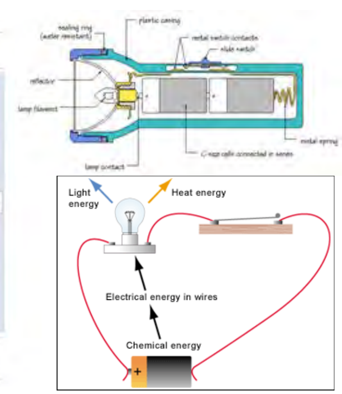
Look to Star Trek, for Trekonomics

6/11/19 ©2017-8 BRUCE CAHAN & URBAN LOGIC, INC. A 501C3 NONPROFIT 14

Think of finance as a circuit board

Electrons move capital through different gatekeepers' hands who transform
Time, Risk and/or Asset type
Maturity, Credit Quality & Liquidity

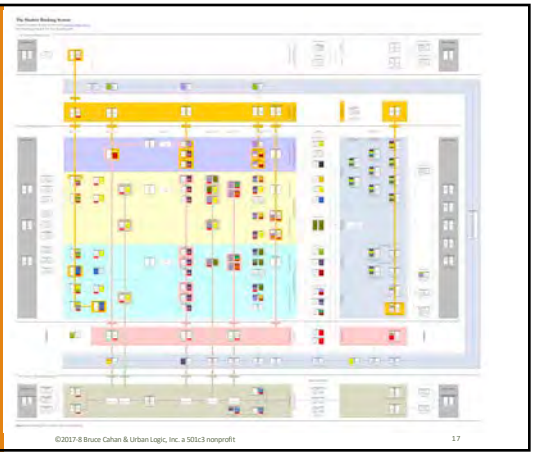
6/11/19 ©2017-19 Bruce Cahan and Urban Logic, Inc., a 501c3 nonprofit 15



6/11/19 ©2017-19 Bruce Cahan and Urban Logic, Inc., a 501c3 nonprofit 16

Simplifying Financial Markets

What functions does society expect of finance?



6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 17

Reimagine space economics

Commodity Markets can

- Grow sustainable space finance at less risk
- Make space exploration affordable and safe for more of humankind
- Improve the science and technology of space commodities and how they interoperate

6/11/19 CONFIDENTIAL MATERIALS 18

Unit of Space Convenience (USC)

"In the general equilibrium theory of economics, the **Unit of Space Convenience (USC)** 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 Quality of Life Elements (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 QoL 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 telecommunication 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), and
- **MC-S** is the Marginal Cost in Space of reducing a unit of f-VaR to level *A* (acceptable f-VaR)."


NEW SPACE ORIGINAL ARTICLE

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

6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 19

Unit of Space Convenience (USC Example 1)

"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 before the wrench being needed is $5 million (MC-E),
- adding a 3D printer and supplies that can manufacture the wrench and other goods on the Space Station costs $2.5 million (MCS),
- twenty-five Periodic Table QoL elements would be assured thereby (QoLs).


NEW SPACE ORIGINAL ARTICLE

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

6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 20

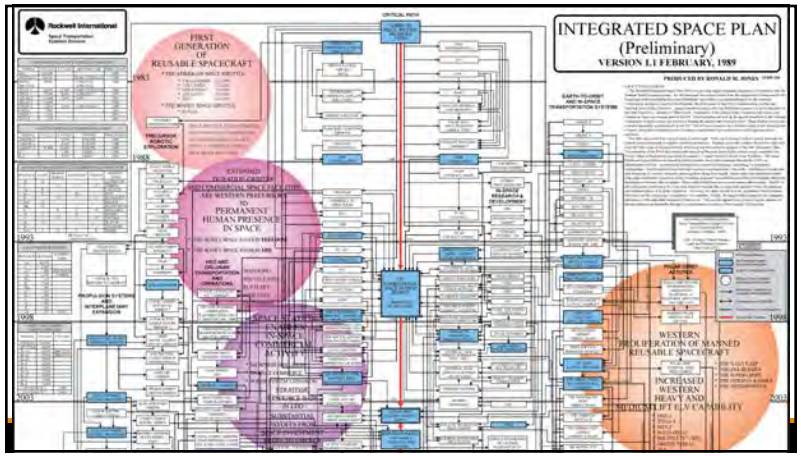
Unit of Space Convenience (USC Example 2)

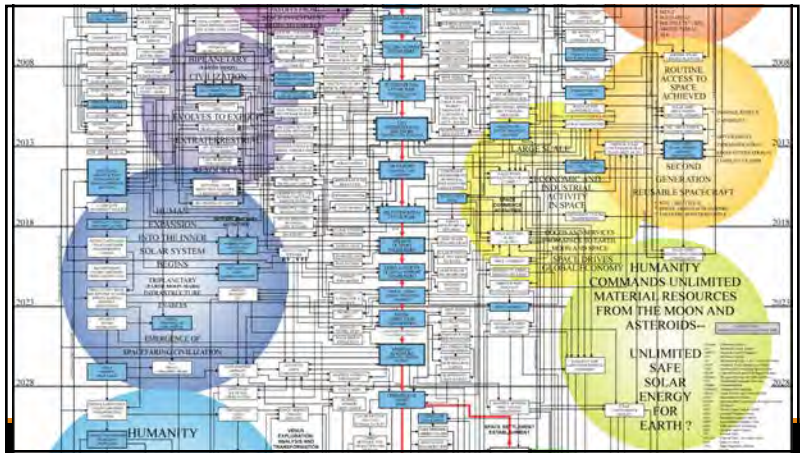
"Take another example: imagine a country's Agriculture and Health Ministries need to monitor weather patterns (e.g., droughts, floods, and heat) that affect crop growing seasons, choice of crops to grow, breed insects, and raise pandemic risks to plants and people (all QoLs with f-VaRs to be reduced), and the Ministers have three economic options27:

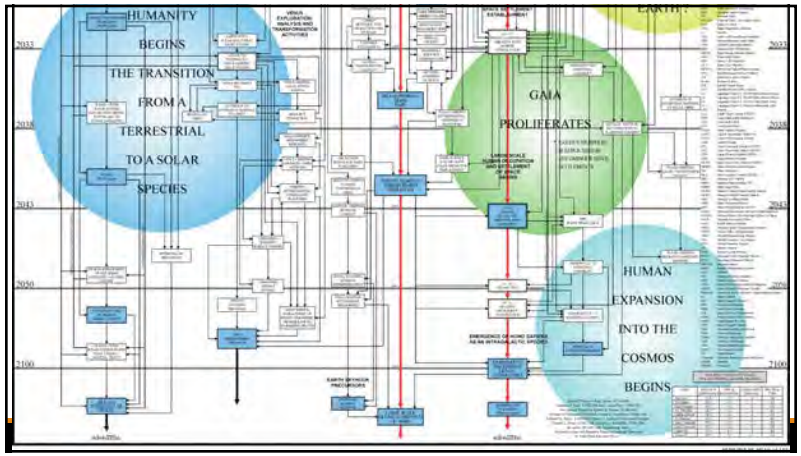
- **Option 1**: Build, launch, and operate the weather satellite service on their own.
- **Option 2**: Building the monitoring satellite on their own and paying for the launch service to place it in orbit.
- **Option 3**: Use an existing weather monitoring service already orbiting its region.

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."


NEW SPACE
ORIGINAL ARTICLE
Outer Frontiers of Banking:
Financing Space Explorers
and Safeguarding Terrestrial Finance







A vibrant space economy needs financial research and imagination

Space Exploration is a new territory for private sector commercialization, finance and market development research

2 papers about banking in space led to more questions


IAC 2015 Jerusalem

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

Bruce R. Cahan
Stanford University, School of Engineering, United States (bcahan@stanford.edu)
Urban Logic, Palo Alto, California (bcahan@ulogic.org)

Irmgard Marboe
University of Vienna, Austria (irmgard.marboe@univie.ac.at)

Henning Rosskel
Stanford University, School of Engineering, United States (hrosskel@stanford.edu)

NEW SPACE
The Journal of Space Entrepreneurship and Innovation

ORIGINAL ARTICLE

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

Bruce R. Cahan[1], Irmgard Marboe[2] and Henning Rosskel[3]

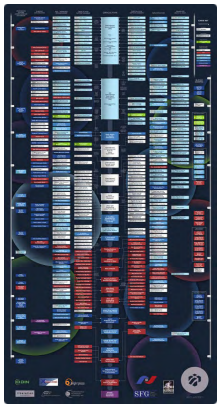
[1]School of Engineering, Stanford University, Stanford, California
[2]Urban Logic, Palo Alto, California
[3]University of Vienna, Vienna, Austria

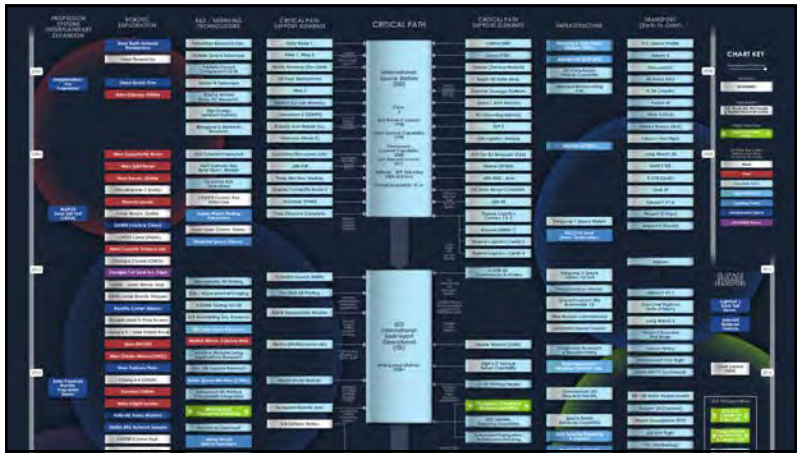
ABSTRACT

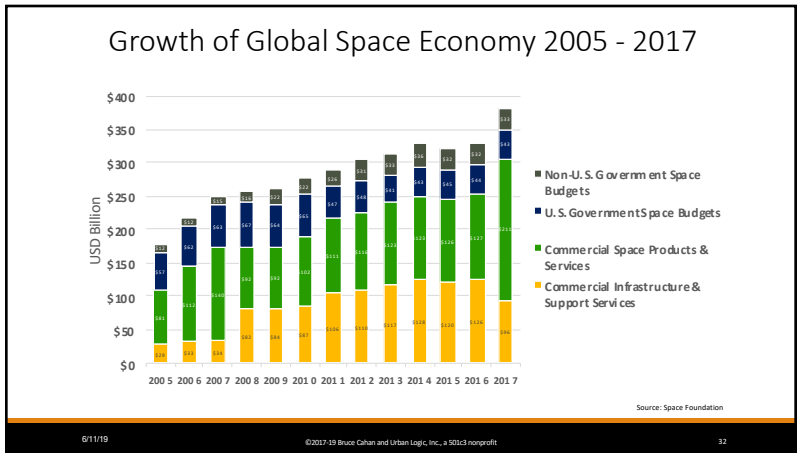
Solutions to Assured Finance

- Underwrite assets based on their USC: Unit of Space Convenience
- Associate each asset with their delivery of meaningful impacts
- Use a Periodic Table of Quality of Life Elements to normalize and quantify impacts as a regional or cluster portfolio

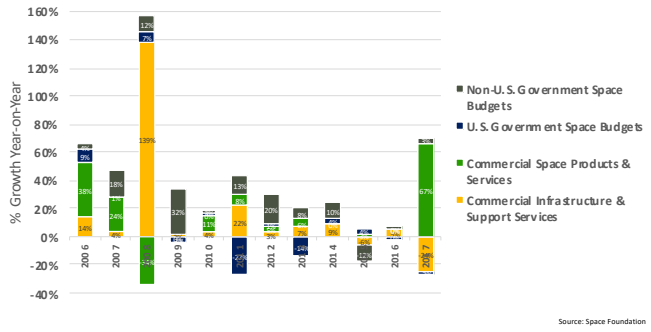
Will 2018's Roadmap of Space Exploration / Economy be limited by lack of persistently creative, diverse financing?







Variable Growth Rate of Global Space Economy 2005 - 2017



Source: Space Foundation

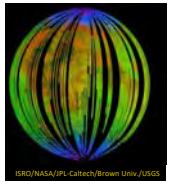
When space finance is political, the space economy's safety and development is at risk

Could a Commodities Exchange augment space financing?

Are terrestrial commodities exchange apparatus and legislation precedent for a space commodities futures trading exchange?

3rd paper: Creating an Exchange for Space Commodities

Space Commodities Exchange
a platform for growing the space economy



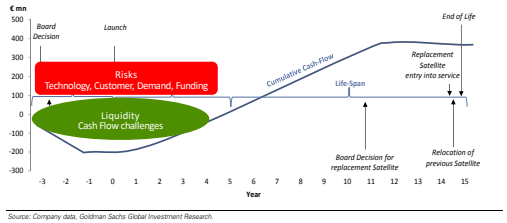
Bruce Cahan
CEO Urban Logic & Lecturer at Stanford School of Engineering

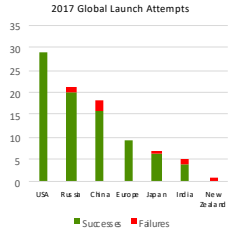
The Space Economy's Problems

To grow, the space economy needs better **liquidity** and **risk transfer** arrangements.

The Space Economy is $350BN today, aiming for $1.1TN by 2040.

Exhibit 7: Typical GEO satellite cash flow
€ mn and years





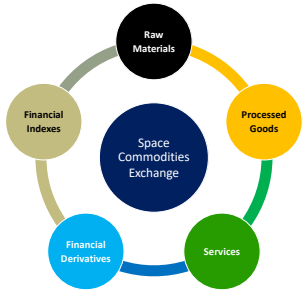
Source: Company data, Goldman Sachs Global Investment Research.

Sources: Morgan Stanley, *Space: Investment Implications of the Final Frontier* (October 2017) Exhibit 66, Satellite Industry Association & Goldman Sachs, *Space: The Next Investment Frontier* (April 2017) Northern Sky Research, *Non-Geo Game Plans & Financial Play* (June 14, 2017)

Solution – adapt a proven business model
Space Commodities Exchange

5 Buckets of Commodities in

- On Earth for space…
- LEO Low Earth Orbit *(first)*
- Lunar Orbit
- Asteroids
- Elsewhere in space



Unique Platform for Assured Space Finance

Symbol for Commodity	Five Buckets of Space Commodities
Raw	1. Raw Materials Futures
Processed	2. Processed Goods Futures
Services	3. Services Futures
Derivatives	4. Financial Derivatives of 1 - 3
Indexes	5. Financial Indexes of 1 - 4

	1. Raw Materials Futures List
RLnrRok	Lunar Rock with Ice
RLnrReg	Lunar Regolith
RLnrLoc	LEO or other protected location in space
RAstRok	Asteroid Rock with minerals

	2. Processed Goods Futures List
PLnrWtr	Lunar Water
PLnrOxy	Lunar Oxygen
PLnrHyd	Lunar Hydrogen
PLnrBlk	Lunar Blocks from Regolith
PAstWtr	Asteroid Water
PAstOxy	Asteroid Oxygen
PAstHyd	Asteroid Hydrogen
PAstMtl	Asteroid Rare Metals

	4. Financial Futures List
FComFut	Commodities Futures (1 - 3)
FCurrFut	Currencies Futures
FLnrCom	LEO Commodities Futures (1 -3)
FLnrCom	Lunar Commodities Futures (1 - 3)
FAstCom	Asteroid Commodities Futures (1 - 3)
FRskLnch	Risk Transfer - Assuring Launch Occurs within Set Period (Earth days originally scheduled)
FRskLeo	Risk Transfer - Assuring LEO Services Operate for Set Duration (Earth months)
FRskLnr	Risk Transfer - Assuring Lunar Services Operate for Set Duration (Earth months)
FRskAst	Risk Transfer - Assuring Asteroid Services Operate for Set Duration (Earth months)

	5. Derivatives Futures List
DLeoIndex	LEO Commodities Index (1, 5 & 10 year index levels)
DLnrIndex	Lunar Commodities Index (1, 5 & 10 year index levels)

	3. Services Futures List
SLnrELeoIn	Launch from Earth to LEO - Inanimate Cargo (kg)
SLnrELeoHu	Launch from Earth to LEO - Human or animal Cargo (kg)
SRtLeoEth	Return from LEO to Earth - Inanimate Cargo (kg)
SRtLeoEHu	Return from LEO Earth - Human or animal Cargo (kg)
SLnrEMn	Launch from Earth to Moon
SRtMnE	Return from Moon to Earth
SLnrEODs	Launch from Earth to Other Destinations
SBndELeo	Bandwidth between Earth & LEO
SBndEMn	Bandwidth between Earth & Moon
SBndLeoODs	Bandwidth between LEO & Other Destinations
SLeoEng	LEO - Energy (kWH)
SLeoFul	LEO - Fuel for transport
SLeoRobM	LEO - Robotic manufacturing of composities
SLeoHab	LEO - Human habitat for tourism or science
SLeoRobR	LEO - Robotic repair, refueling or repositioning of satellites
SLeoImg	LEO - Earth imagery or remote sensing of IoT
SLeoElbs	LEO - Earth Location Based Services (LBS), Navigation & GPS from LEO
SLeoData	LEO - In-space processing or storage of data (like AWS)
SLeoDebris	LEO - Debris removal or defense of satellites
SLnrEng	Lunar - Energy (kWH)
SLnrFul	Lunar - Fuel for transport
SLnrRobM	Lunar - Robotic manufacturing or mining
SLnrHab	Lunar - Human habitat for tourism or science
SLnrRobR	Lunar - Robotic repair, refueling or repositioning of lunar assets
SLnrImg	Lunar - Surface and near surface imagery or remote sensing of IoT
SLnrElbs	Lunar - Lunar Location Based Services (LBS), Navigation & GPS
SLnrData	Lunar - Surface processing or storage of data (like AWS)
SLnrDebris	Lunar - Debris removal or defense of lunar assets
SAstEng	Asteroid - Energy (kWH)
SAstFul	Asteroid - Fuel for transport
SAstRobC	Asteroid - Robotic capture or deflection
SAstRobM	Asteroid - Robotic manufacturing or mining
SAstHab	Asteroid - Human habitat for tourism or science
SAstRobR	Asteroid - Robotic repair, refueling or repositioning of surface assets
SAstImg	Asteroid - Surface and near surface imagery or remote sensing of IoT
SAstElbs	Asteroid - Location Based Services (LBS), Navigation & GPS

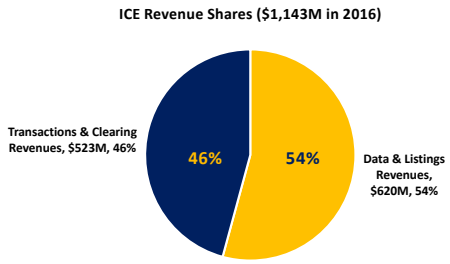
Benefits of Space Commodities Exchange

Party	Commodity	Liquidity	Risk of Demand	Risk of Technology
Suppliers	Launch to LEO	Pre-sell Future Launch Capacity as a Commodity = Earlier Cash Flow	Market data on Launches needed where and when	Hedge Component Failure as derivative or as replaceable commodity
Buyers	Launch to LEO	Hedge Launch failure or delay by access to others' Launch Capacities	Transparency of launch commodity pricing = wider market participation	Commodity standards reduce bespoke risks of assembling space operations

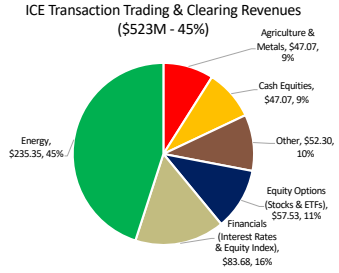
Benefits of Space Commodities Exchange

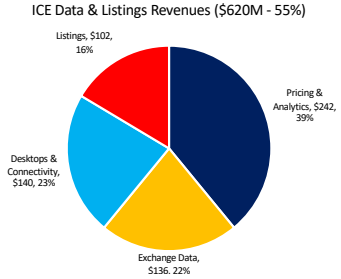
Party	Commodity	Liquidity	Risk of Demand	Risk of Technology
Suppliers	Launch to LEO	Pre-sell Future Launch Capacity as a Commodity = Earlier Cash Flow	Market data on Launches needed where and when	Hedge Component Failure as derivative or as replaceable commodity
Buyers	Launch to LEO	Hedge Launch failure or delay by access to others' Launch Capacities	Transparency of launch commodity pricing = wider market participation	Commodity standards reduce bespoke risks of assembling space operations
Space Investors	Derivatives or Indexes of Commodities	Can readily price & sell portfolio of space commodities on Exchange	Demand for specific commodities & clusters of commodities is easy to analyze	Technology hedge derivatives become investment assets
Government	Growing & protecting Space Economy	Regardless of annual space & defense appropriations, space economy has vitality through private market	Commodities Exchange transactions plots "real world" roadmap for how Space Economy will grow & role of government	Exchange improves price, performance & redundancy of commodities essential to government space operations

Terrestrial Exchange Revenue Example
Intercontinental Commodities Exchange (ICE)



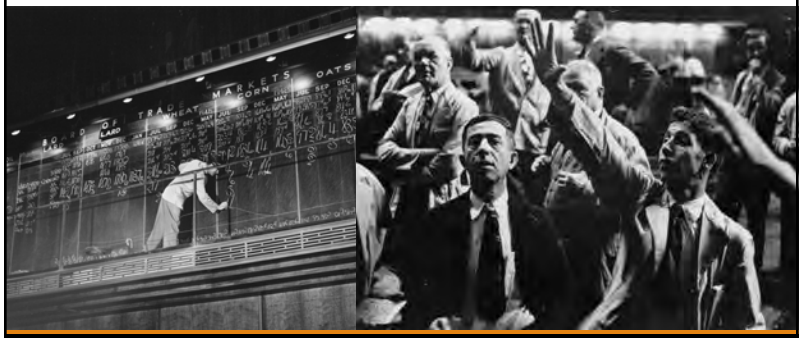
Terrestrial Exchange Revenue Example
ICE Intercontinental Exchange (2016)





Historical Precedents

Especially for commodity producers, safety in well functioning exchange



Historical Precedents (Partial list)

Commodities Exchange examples:

- 1571 Royal Exchange opened in London
- 1710 Dojima Rice Exchange opened in Osaka, Japan
- 1848 Chicago Board of Trade (CBOT) organized
- 1864 CBOT listed the first standardized "exchange traded" forward contracts called *futures contracts*
- 1877 London Metal Market and Exchange Company (London Metal Exchange) opened
- Today, Chicago Mercantile Exchange (CME or the "Merc") the CBOT's successor, trades agricultural, industrial and other physical commodities, as well as financial derivatives and futures

Historical Functions of an Exchange

Regulates a "Level Playing Field" operated in public interest to stabilize economic supply and demand of essential commodities at fair price

Standardizes

- Commodity Definition and Minimum Quality
- Contract Terms: Price, Delivery, Recourse
- Marketability/Transferability of Contract Rights

Register, Clear and Settle Commodities Contracts

Exchange is Central Counterparty to Validate Parties to and Enforce Contract

Market Transparency:

- Contracts' individual and aggregate value, volume and price movements
- Trusted Source of Market Health and Trends Data Source for sellers, buyers, investor and insurers of commodities

Transcontinental Railroad sparked the need for a Commodities Exchange in Chicago

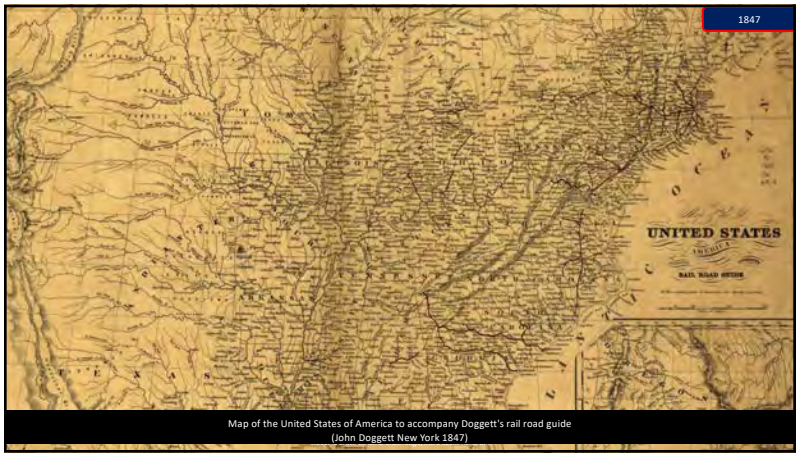
Railroads, steel mills, locomotive manufacturers and their bankers needed iron and steel rails of consistent strength and quality for the weight of the locomotives

Businesses, farmers, grain and livestock producers using the Transcontinental Railroad needed a consistent marketplace to offer, trade, consign and finance their goods and services

1807

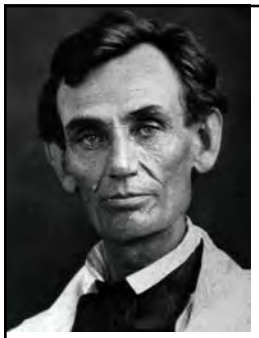
Map of the discoveries of Capt. Lewis & Clark from the Rocky Mountain and the River Lewis to the Columbia River at the north Pacific Ocean (Lewis & Clark Philadelphia 1807)

1847



Map of the United States of America to accompany Doggett's rail road guide (John Doggett New York 1847)

July 1862



President Abraham Lincoln signed the Pacific Railroad Act of 1862 into law to set the gauge of the tracks, allocate land grants and thereby guarantee building of the transcontinental railroad

Unifying Track Gauge & Steel Quality might unify the Nation

"Before the [Civil War], parochialism took form in the patchwork of different railroad gauges that preserved local control and prevented the efficient through-shipment of goods.

In 1861 eight changes of cars due to gauge were necessary to complete a trip from Philadelphia to Charleston.

After the [Civil War], parochialism was scarcely dampened by the Northerners' imposition of Reconstruction.

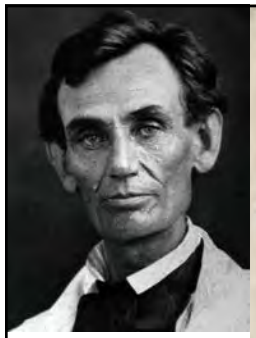
While communities in both the North and South initially competed enthusiastically for railroads, in time Southerners became increasingly alarmed with railroads whose corporate form seemed to embody foreign dominance and whose ownership in fact passed increasingly into Northern hands.

Concerning the major southern railroads (100 miles or more in length), Northerners controlled 21 percent of the region's mileage in 1870, 48 percent in 1880, 88 percent in 1890, and 96 percent in 1900"

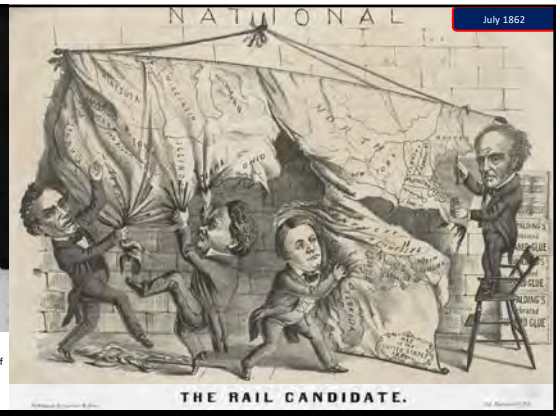
Source: Thomas J. Misa, *A Nation of Steel: The Making of Modern America, 1865-1925* (Johns Hopkins University Press, 1995)

An Act to aid in the construction of a railroad and telegraph line from the Missouri river to the Pacific ocean, and to secure to the government the use of the same for postal, military, and other purposes (July 1862)

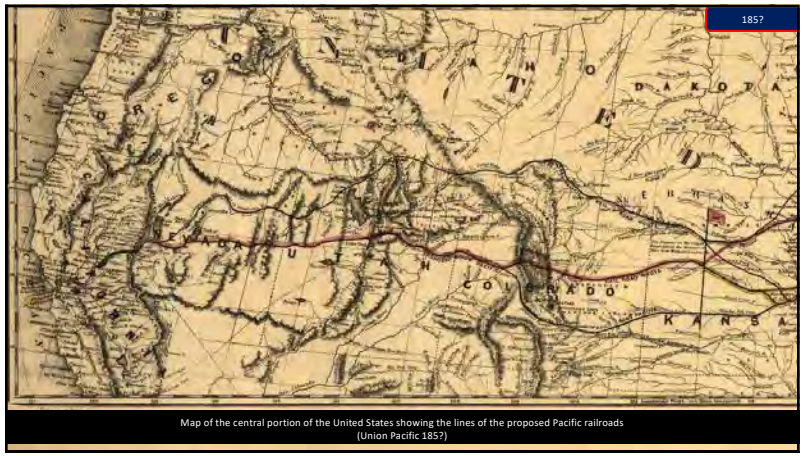
July 1862



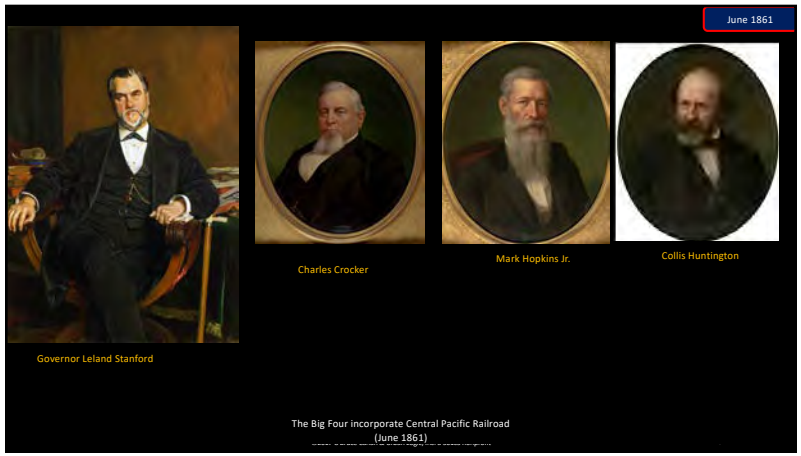
President Abraham Lincoln signed the Pacific Railroad Act of 1862 into law to set the gauge of the tracks, allocate land grants and thereby guarantee building of the transcontinental railroad



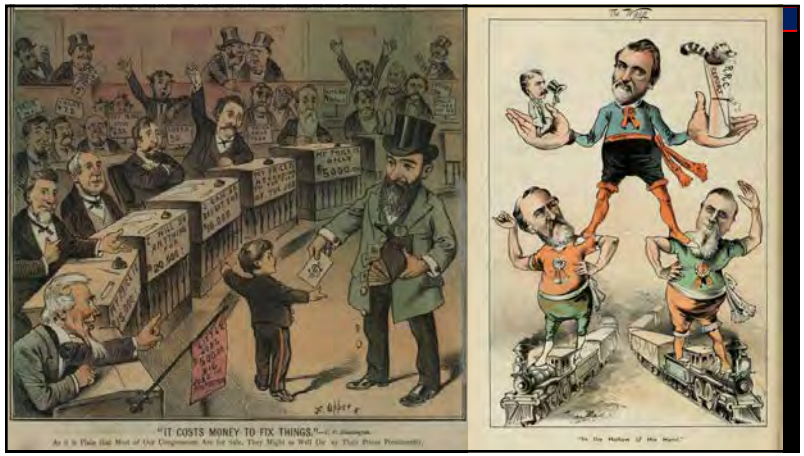
An Act to aid in the construction of a railroad and telegraph line from the Missouri river to the Pacific ocean, and to secure to the government the use of the same for postal, military, and other purposes (July 1862)



Map of the central portion of the United States showing the lines of the proposed Pacific railroads
(Union Pacific 185?)



The Big Four incorporate Central Pacific Railroad
(June 1861)



May 1865

Pacific Railroad Bond issued by San Francisco
(1865)

1862

Rail-road and military map of the United States, Mexico, the West Indies
(Joseph Colton 1862)

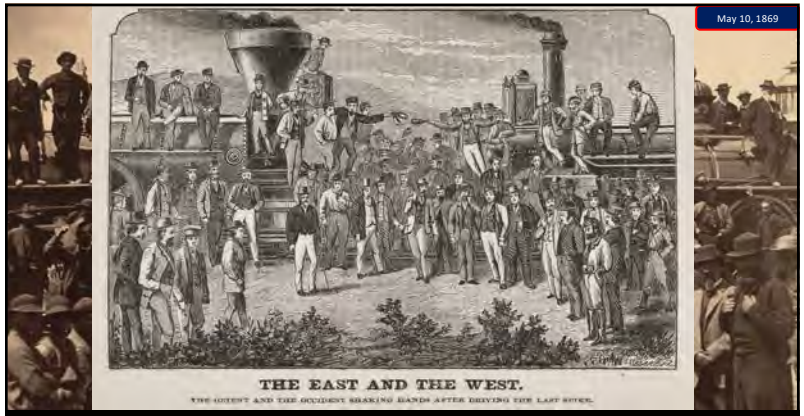
1863

County map of the United States and Canadas showing battle fields, railroads
(Lloyd's 1863)

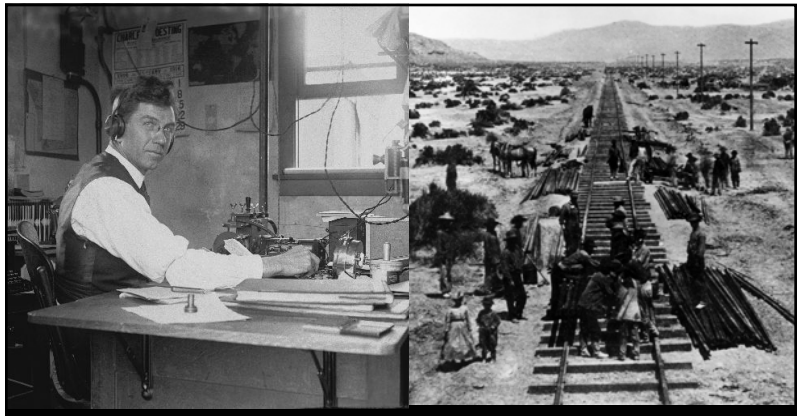
May 10, 1869

Central Pacific Railroad from the West meets Union Pacific Railroad from the East
(Promontory Summit, Utah 1869)

May 10, 1869



Central Pacific Railroad from the West meets Union Pacific Railroad from the East
(Promontory Summit, Utah 1869)

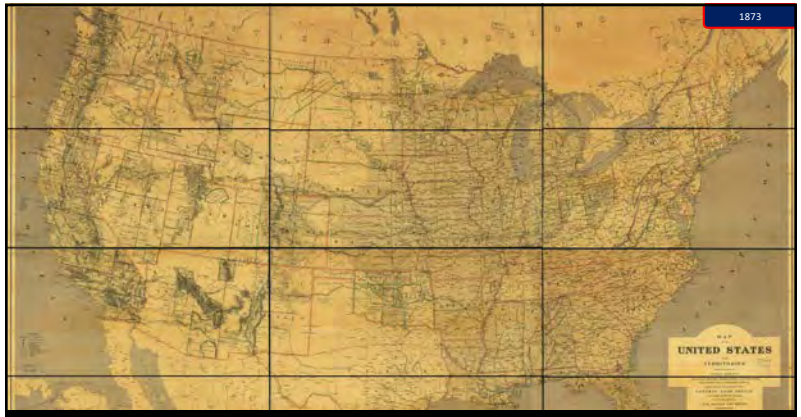


Pursuant to the Pacific Railway Act, telegraph poles and wires were strung
alongside railroad tracks to pair communications with transportation services

1871

Railroad & commercial map of the United States and Canada showing county boundaries
(G.W. & C.B. Colton & Co. 1871)

1873



Map of the United States and territories showing the extent of public surveys, Indian and military reservations, land grant R.R.; rail roads, canals, and other details
(U.S. General Land Office 1873)

1876

Centennial American Republic and railroad map of the United States and of the Dominion of Canada
(Watson & Gaylord 1875)

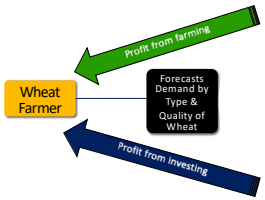
1883

Map of the Union Pacific Railway, the short, quick and safe line to all points West
(Union Pacific Railway - Chicago, 1883)

Commodities Markets intermediate highest value exports from places where they can be best produced

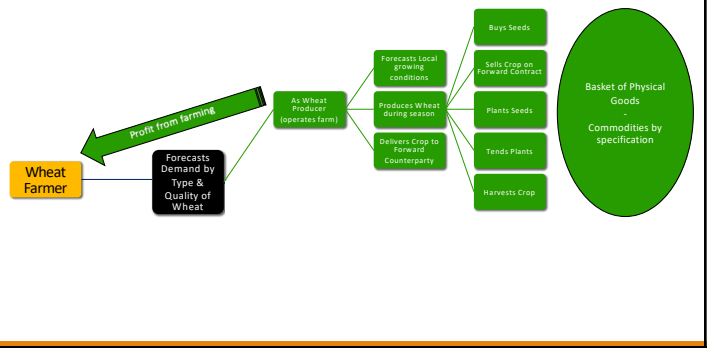
6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 67

How Grain Commodity Markets Work



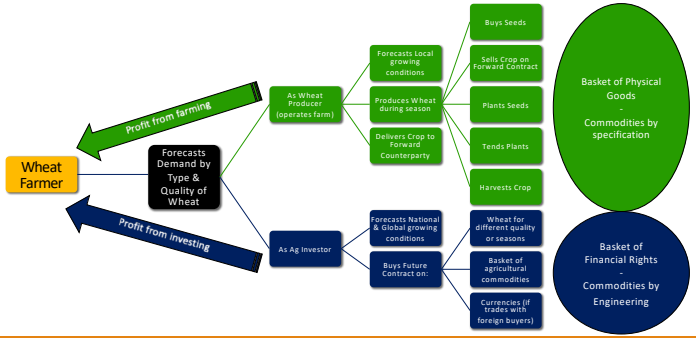
6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 68

How Grain Commodity Markets Work

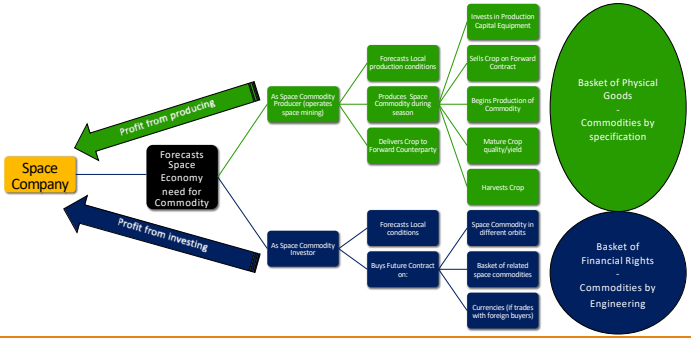


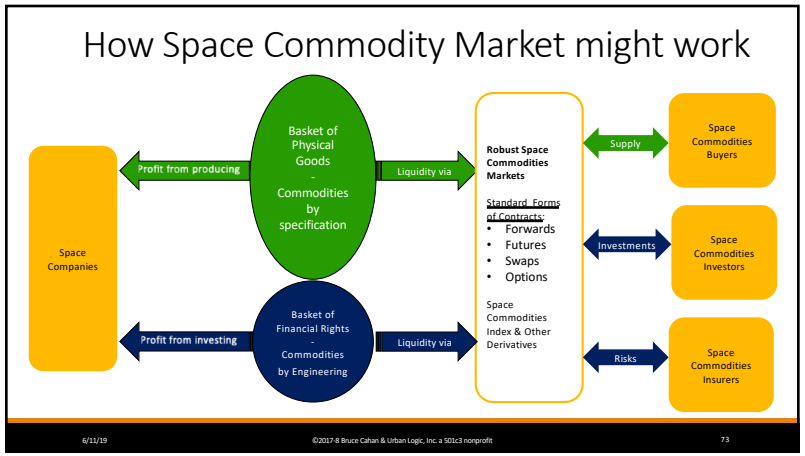
How Grain Commodity Markets Work

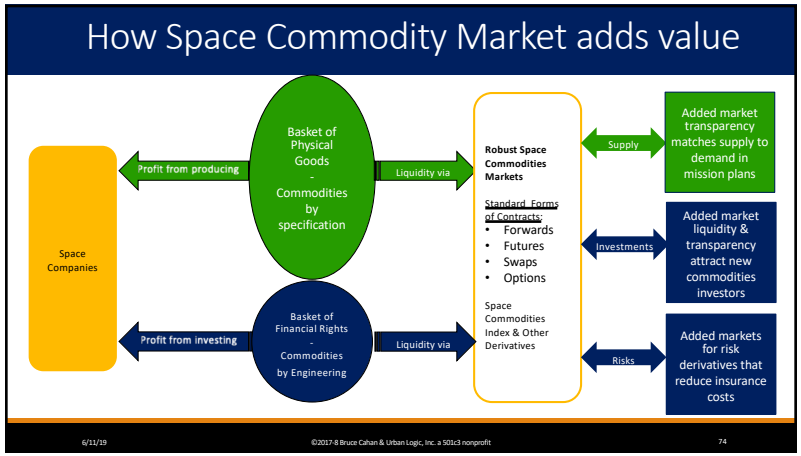
How Grain Commodity Markets Work

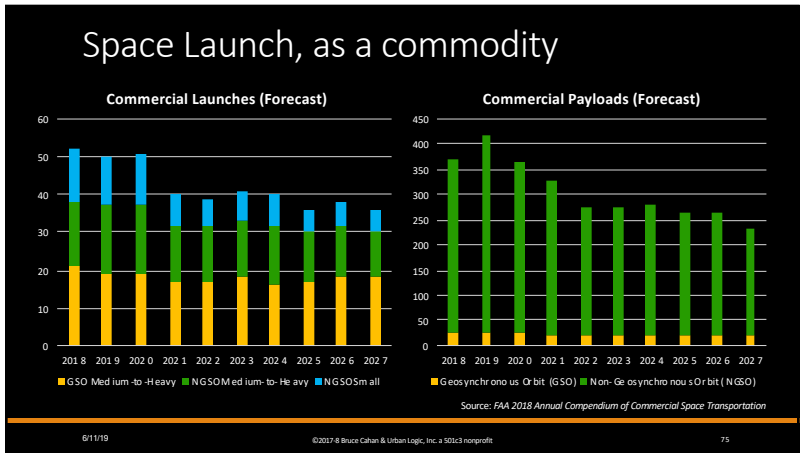


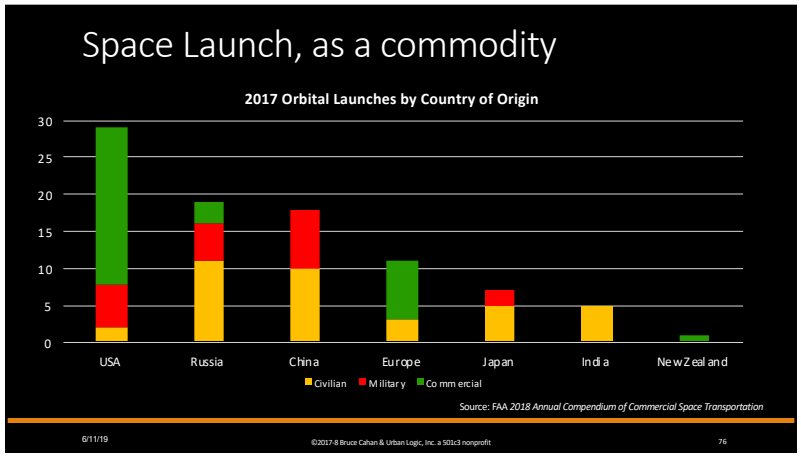
How Space Commodity Market might work



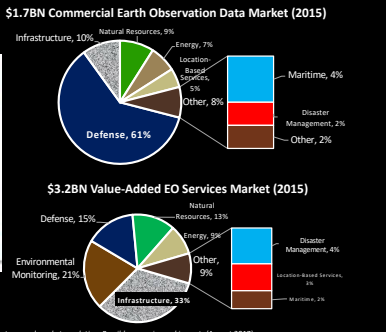






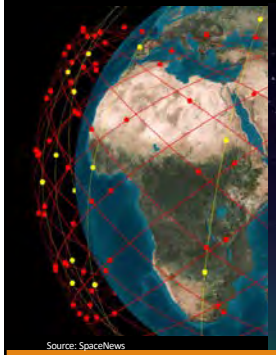


Space Imagery, as a commodity



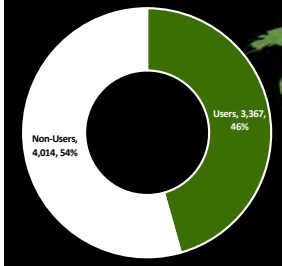
Source: Gil Denisa, Alain Claverlea et al, *Towards disruptions in Earth observation? New Earth Observation systems and markets evolution: Possible scenarios and impacts* (August 2017)

Space Bandwidth, as a commodity



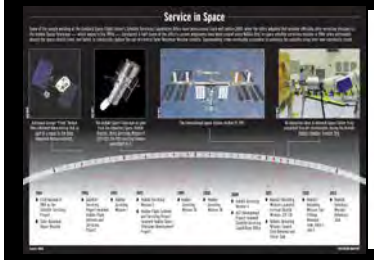
Source: SpaceNews

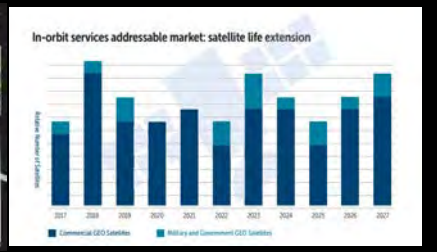
Space Bandwidth, as a global development commodity



Source: Internet Live Stats

Space Refueling & Servicing, as commodities

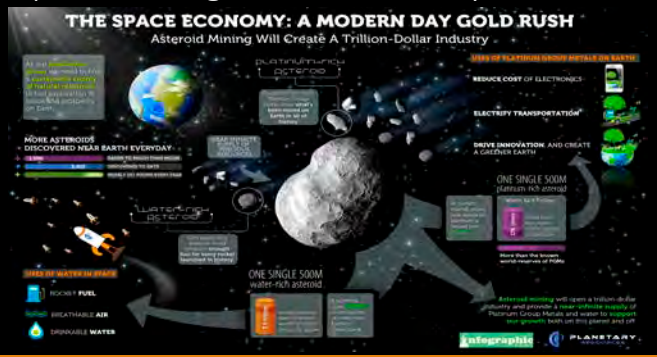




Source: SpaceNews

Space Debris, as a commodity

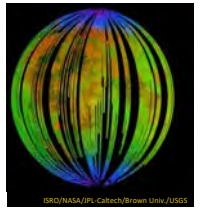
Space Mining, as a commodity



What happens without a Space Commodities Exchange?

Is a Commercial Space Economy or National Security
better off with or without commodities exchange markets?

Space Commodities in Service of National Security



Bruce Cahan
CEO Urban Logic
bcahan@urbanlogic.org

Tim Locke
U.S. Air Force Space and Missile Systems Center
timothy.locke@us.af.mil

Presented to
2018 AIAA Space & Astronautics Forum Orlando
September 17 - 19, 2018

Tim Locke, Major - Advanced Space Technologies

U.S. Air Force Space Command - Space and Missile Systems Center, El Segundo, CA

Space Innovator

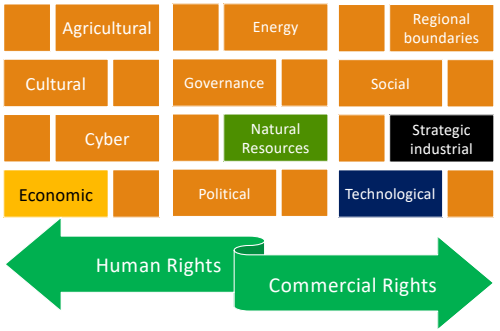
Major Locke has the pulse of Science and Technology (S&T) applications for Space Enterprise Vision. He has devised or advanced 3 key innovations to benefit SEV resilience: 1) agile thruster technology, 2) Type 1 Crypto for small satellites and 3) non-Keplerian orbits for agile space mission design. He has an entrepreneurial spirit: he has started his own small businesses and can easily translate government strategies to small and then to large business strategic vision, enabling faster IRAD alignment with industry partners. Maj Locke can move the world using the leverage of the government S&T portfolio. --Dr. Roberta Ewart, SMC Chief Scientist

Education

Masters Electrical, Electronics & Communications Engineering Air Force Institute of Technology - Graduate School of Engineering & Management
BS Electrical Engineering Montana State University at Bozeman

LinkedIn Profile https://www.linkedin.com/in/timothy-locke-280b0239/

National Security is multidimensional



National Security depends on assured access to outer space

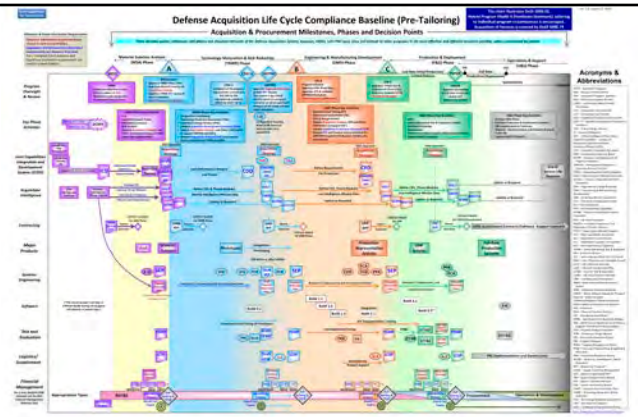
According to the U.S. National Security Space Strategy:

"Space is vital to U.S. national security and our ability to understand emerging threats, project power globally, conduct operations, support diplomatic efforts, and enable global economic viability. As more nations and non-state actors recognize these benefits and seek their own space or counterspace capabilities, we are faced with new opportunities and new challenges in the space domain. The current and future strategic environment is driven by three trends – space is becoming increasingly *congested, contested* and *competitive*." (20)

Recent strategic threat assessments require assured space capabilities as a cornerstone of U.S. national security:

"Space capabilities enable the American way of warfare by making it possible for U.S. military commanders and forces to see the battlespace more clearly, communicate with certainty, navigate with accuracy, and strike with precision. Acknowledging this importance and consistent with prior administrations of both political parties, the current National Security Strategy recognizes that unimpeded access to and use of space is a vital national interest.

"Our adversaries and potential adversaries have noted these significant advantages and have moved aggressively to field forces that can challenge our space capabilities from the ground, in space, and through cyberspace. From simple (and widely available and affordable) jammers to highly sophisticated antisatellite (ASAT) weapons, today the U.S. is facing serious threats in a domain that is increasingly an arena for conflict. Denying U.S. space capabilities is a central tenet of adversary strategies designed to diminish our prestige and raise the risks and costs of intervention in regional affairs." (21)



CFTC's 23 Core Principles to assure Commodities Market Functions Smoothly

- Designation as Contract Market
- Compliance With Rules
- Contracts Not Readily Subject to Manipulation
- Prevention of Market Disruption
- Position Limitations or Accountability
- Emergency Authority
- Availability of General Information
- Daily Publication of Trading Information
- Execution of Transactions
- Trade Information
- Financial Integrity of Transactions
- Protection of Markets and Market Participants
- Disciplinary Procedures
- Dispute Resolution
- Governance Fitness Standards
- Conflicts of Interest
- Composition of Governing Boards of Contract Market
- Recordkeeping
- Antitrust Considerations
- System Safeguards
- Financial Resources
- Diversity of Boards of Directors
- Securities and Exchange Commission

6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 89

CFTC's 23 Core Principles to assure Commodities Market Functions Smoothly

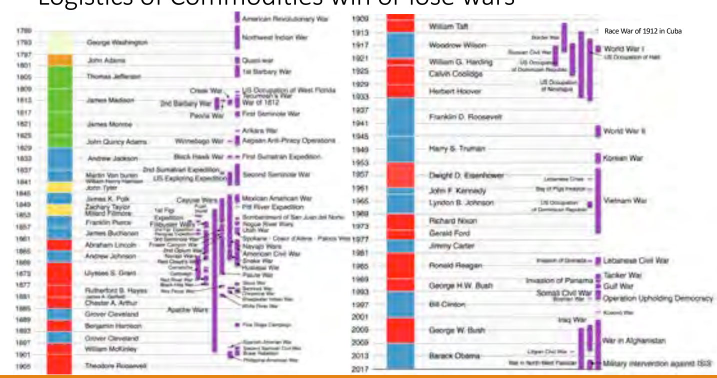
- Designation as Contract Market
- Governance Fitness Standards
- Conflicts of Interest
- Composition of Governing Boards of Contract Market
- Financial Resources
- Diversity of Boards of Directors
- Contracts Not Readily Subject to Manipulation
- Financial Integrity of Transactions
- Availability of General Information
- Daily Publication of Trading Information
- Trade Information
- Recordkeeping
- Compliance With Rules
- Execution of Transactions
- Prevention of Market Disruption
- Protection of Markets and Market Participants
- Disciplinary Procedures
- System Safeguards
- Emergency Authority
- Position Limitations or Accountability
- Dispute Resolution
- Antitrust Considerations
- Securities and Exchange Commission

6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 90

4th paper: Space Commodities in Service of National Security

6/11/19 ©2017-19 Bruce Cahan and Urban Logic, Inc., a 501c3 nonprofit 91

Logistics of Commodities win or lose wars



6/11/19 ©2017-8 Bruce Cahan & Urban Logic, Inc. a 501c3 nonprofit 92

Cold War Lessons of Space Warfare

1960, May 5 – U.S. Air Force Pilot Gary Powers' U2 spy plane shot down over USSR

1961 - NRO's AFTRACK Program Satellite Surveillance Vehicle 1107 flew 38 orbits and then lost power

1960s – Corona & later programs relied on photographic film obscured by cloud cover

CubeSats and commercial digital imagery and image processing have improved surveillance of regions that would be difficult or impossible to monitor via aircraft flyover

Early recognition of the potential of aggressors to disable or interfere with LEO-based surveillance satellites and data

Logistics of Commodities are essential for peacekeeping

United Nations peacekeeping missions and hundreds of nongovernmental organization (NGO) projects require logistical support and assurance to

- safeguard personnel,
- build local housing, healthcare and infrastructure and
- respond to migration, pandemic, systemic or disaster conditions. (39) (40)

DoD Continuing Resolutions + Analog Military Procurement = how to lose the war in space

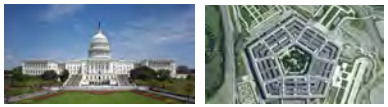
Delays in Defense Appropriations FY 1977 – 2018

Shay Assad, DoD Director of Defense Pricing and Defense Procurement and Acquisition Policy:

"What we're not interested in doing is changing 400-500 days that it takes to do something to 475 days."

"What we really want to get to is changing 400-500 days to 30."

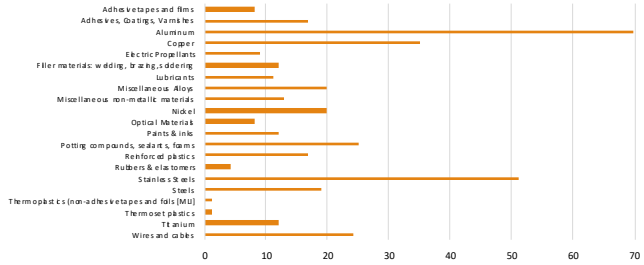
(Source: Federal News Radio)



Beyond Earth's LEO, national security will require innovations in procurement that mitigate inherent challenges of getting commodities and supplies to the right place terrestrially and in space at the right time in adequate quantity and quality.

Space Assets & Services Supply Chains: Materials, Suppliers, Markets, Finance

Table 1: # alloys & variants used in Space



Space Assets are designed & built in stages

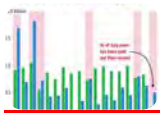

Design Thinking


Innovation Adoption Curve


Market Identified


Technology Readiness Level Achieved

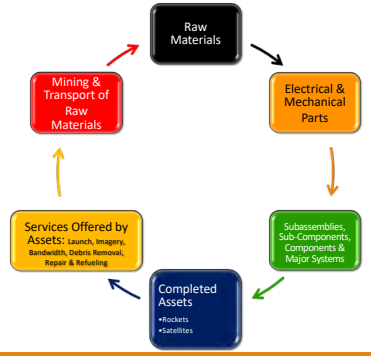

Finance


Insurance

Regulation
Domestic + International


Manufacturing

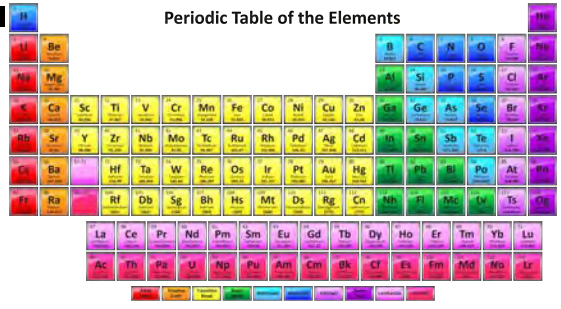
Space Assets are designed & built in stages



Minerals are scarce and geopolitical

USGS' List of 35 Critical Minerals (Table 2)

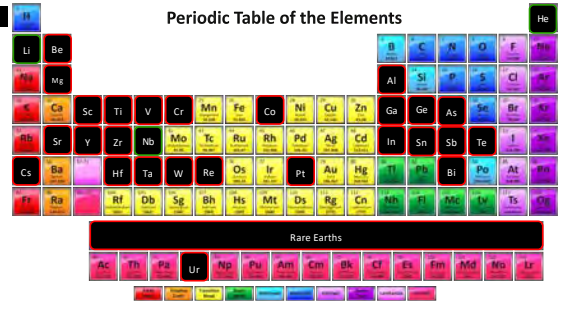
Aluminum	Magnesium
Antimony	Manganese
Arsenic	Niobium
Barite	Platinum
Beryllium	Potash
Bismuth	Rare Earths
Cesium	Rhenium
Chromium	Rubidium
Cobalt	Scandium
Fluorspar	Strontium
Gallium	Tantalum
Germanium	Tellurium
Graphite (natural)	Tin
Hafnium	Titanium
Helium	Tungsten
Indium	Uranium
Lithium	Vanadium
	Zirconium



Minerals are scarce and geopolitical

USGS' List of 35 Critical Minerals (Table 2)

Aluminum	Magnesium
Antimony	Manganese
Arsenic	Niobium
Barite	Platinum
Beryllium	Potash
Bismuth	Rare Earths
Cesium	Rhenium
Chromium	Rubidium
Cobalt	Scandium
Fluorspar	Strontium
Gallium	Tantalum
Germanium	Tellurium
Graphite (natural)	Tin
Hafnium	Titanium
Helium	Tungsten
Indium	Uranium
Lithium	Vanadium
	Zirconium



China's Relative Competitive Advantage over U.S. in Obtaining Strategic Minerals (HHI score)

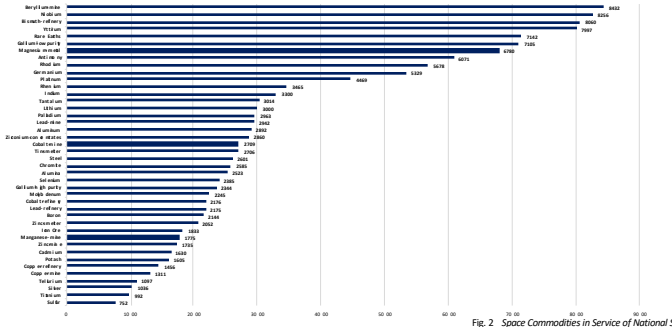


Fig. 2 *Space Commodities in Service of National Security*

Global Commodities Exchanges as Toll Booths

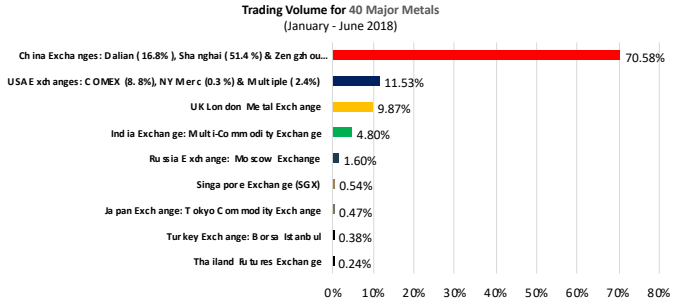


Fig. 9 *Space Commodities in Service of National Security*

Helium

Global Reserves & Production (2017 million m^3)

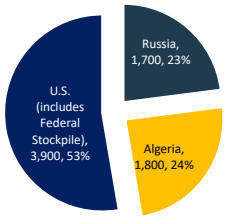


Fig. 3 2017 Global Helium Reserves (million m^3)

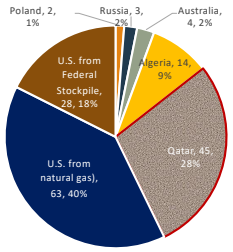


Fig. 4 2017 Global Helium Production (million m^3)

Lithium

Global Reserves & Production (2017 metric tons)

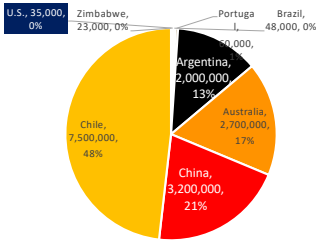


Fig. 5 2017 Global Lithium Reserves (metric tons)

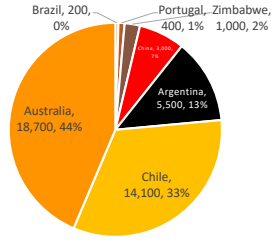


Fig. 6 2017 Global Lithium Production (metric tons)

Niobium

Global Reserves & Production (2017 metric tons)

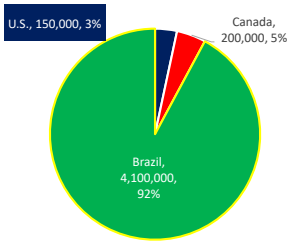


Fig. 7 2017 Global Niobium Reserves (metric tons)

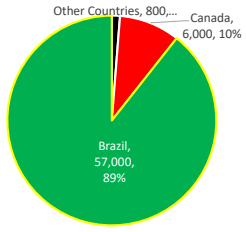


Fig. 8 2017 Global Niobium Production (metric tons)

Comparing Future National Security Scenarios

Scenario	Commercially Viable Technologies Alter Resource Use	Economic Competition for Resources	Warfighting	Space Law Assures Resource Claims	Commodities Stockpiles Assures Supply	Commodities Exchange Balances Supply & Demand
Good Earth	Yes	Yes				Yes
Warfare on Earth	Yes	Yes	Yes		Yes	Yes
Good Space	Yes	Yes		Yes		Yes
Space Too Far	Yes	Yes			Yes	Yes
Warfare in Space	Yes	Yes	Yes		Yes	Yes

Table 4 *Space Commodities in Service of National Security*

Joint Chiefs' Space Operations Doctrine

Passive, Observational and Communications Capabilities

- Space Situational Awareness
- Space Control, Positioning, Navigation and Timing
- Intelligence
- Surveillance and Reconnaissance
- Satellite Communications (**SATCOM**) and Satellite Operations
- Environmental Monitoring
- Missile Warning
- Nuclear Detonation Detection
- Space Launch & Lift

Procurement Strategy:
Outsource - Spur Commercial Space Industry to Provide as COTS
Leverages Just in Time Manufacturing, Supply Chains & Non-Governmental Markets

Active Capabilities

- Warfighting Command and Control
- Intelligence Gathering
- Fires, Movement and Maneuver
- Protection
- Sustainment
- Information Use and Analysis

Procurement Strategy:
Pure or Hybrid Governmental Function that can only partially be outsourced
Relies on Commercial Supply Chains

Commercial Benefits of Space Commodities Exchange

Party	Commodity	Liquidity	Risk of Demand	Risk of Technology
Suppliers	Launch to LEO	Pre-sell Future Launch Capacity as a Commodity = Earlier Cash Flow	Market data on Launches needed where and when	Hedge Component Failure as derivative or as replaceable commodity
Buyers	Launch to LEO	Hedge Launch failure or delay by access to others' Launch Capacities	Transparency of launch commodity pricing = wider market participation	Commodity standards reduce bespoke risks of assembling space operations
Space Investors	Derivatives or Indexes of Commodities	Can readily price & sell portfolio of space commodities on Exchange	Demand for specific commodities & clusters of commodities is easy to analyze	Technology hedge derivatives become investment assets
Government	Growing & protecting Space Economy	Regardless of annual space & defense appropriations, space economy has vitality through private market	Commodities Exchange transactions plots "real world" roadmap for how Space Economy will grow & role of government	Exchange improves price, performance & redundancy of commodities essential to government space operations

National Security Benefits of Space Commodities Exchange

Solution to Current Problem	Mitigation of Current Risks and Costs for National Security
Standardizes Full Lifecycle of Space Commodities, their financing and risk mitigation	Exchange creates a platform for predicting, matching, financing and insuring Supply and Demand for Space Commodities on Earth, in LEO and beyond
Fills Gaps in Space Law for Commercial Space Activities	Violation or failure to honor Exchange Contracts carries Suspension, Debarment, Guarantee and other penalties Theft of, or threat to, an Exchange Member's assets carries similar penalties International Actors with valuable Space Commodities will behave cooperatively
Grows Appetite of Space Investors, Lenders & Insurers	Transparency of Space Commodities traded for current and future delivery lets everyone readily price and sell a more diverse portfolio of Space Commodities on Exchange
Makes Government Space Procurement faster, smarter, cheaper	Standardized Exchange Commodity Definitions and Contract Terms speed DoD Procurement via a Functional Platform for Tapping into the Commercial Market More stable investments in the Space Economy grow competition and reduce DoD over-reliance on individual firms, reducing bankruptcy supply and technology (TRL) risks Regardless of annual Congressional Space and Defense appropriations, Space Economy has vitality through private market

National Security's Two-Sided Coin

Source: Daniel Carr Designs

National Security's Two-Sided Coin

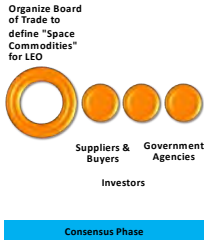
Without the Space Commodities Exchange	With the Space Commodities Exchange
Space Economy grows slower	Space Economy grows faster
Benefits of Exchange are unavailable	Benefits of Exchange save DoD money, time, waste and technology TRL risks
Rely more on Bespoke Procurement	Exchange strengthens Supply Chains for Space Commodities
Increased Risks of Supply Chain uncertainties	A U.S. regulated Exchange gives U.S. Financial Regulatory Oversight to detect and deter bad actors or their misuse of Space Commodities
National Security risks of Commercial Space are more a function of Foreign Commodities and Corporate Markets who answer to Foreign State Actors, Sovereign Investors and Agendas	Faster growth of Space Economy accelerates National Security needs to protect it sooner across a wider range of actors and threats

Traction to Date

Widespread support for moving forward from diverse private and public groups:

- ❑ October 2016 National Space Society Recommendation #4 to the President
- ❑ Jan – Dec 2017 Validation with Traditional & New Space Suppliers & Customers
- ❑ June 2017 NewSpace Conference Space Commodities panel
- ❑ August 2017 US Air Force conversations begin
- ❑ January 2018 NewSpace Journal peer-reviewed paper accepted
- ❑ January 2018 Commodities Futures Trading Commission (**CFTC**) meeting
- ❑ February 2018 Securities and Exchange Commission (**SEC)** meeting
- ❑ March 2018 Japanese Government Space Conference panel (I-ISEF)
- ❑ July 2018 NASA and CFTC briefed on Space Commodities Exchange
- ❑ September 2018 Presented at AIAA: American Institute of Aeronautics & Astronautics
- ❑ November 2018` Briefed White House Office of Space Commerce
- ❑ December 2018 Briefed to Defense Innovation Unit (DIU) Space Portfolio Lead

Roadmap for Space Commodities Exchange

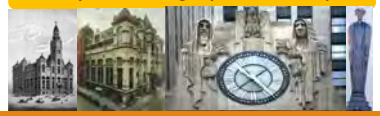


History of Chicago Mercantile Exchange (CME)

1848 - 1999

1848 Chicago Board of Trade (CBOT) founded as first futures exchange
1851 CBOT offers World's 1st Forward Contract
1865 Starts trading Standardized Futures Contracts
1898 Nonprofit Chicago Butter and Egg Board (CBEB) founded
1919 CBEB converts to Chicago Mercantile Exchange (CME), still nonprofit
1926 CBOT Clearing formed to guarantee trades
1972 CME first trades financial futures contracts
1975 CBOT first trades interest rate futures
1982 CME first trades stock index futures
1987 CME prototypes electronic trading platform
1999 CME trades first weather-based futures

For 152 years, Exchange operates as non-profit



2000

CME Demutualized and converted from nonprofit member organization to for-profit company

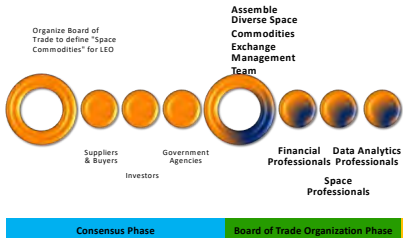
2002

CME Group IPOs

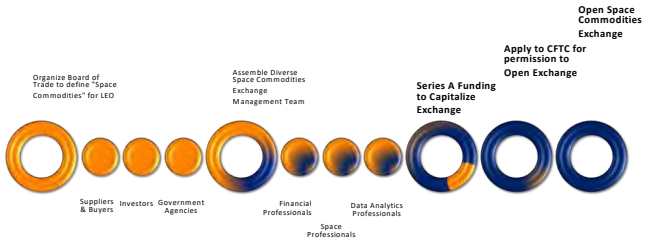
Since 2000, Exchange operates as for-profit

Board of Trade for Space Commodities Exchange
an inclusive, neutral space economy platform

Roadmap for Space Commodities Exchange



Roadmap for Space Commodities Exchange



Questions? Bruce Cahan bcahan@urbanlogic.org