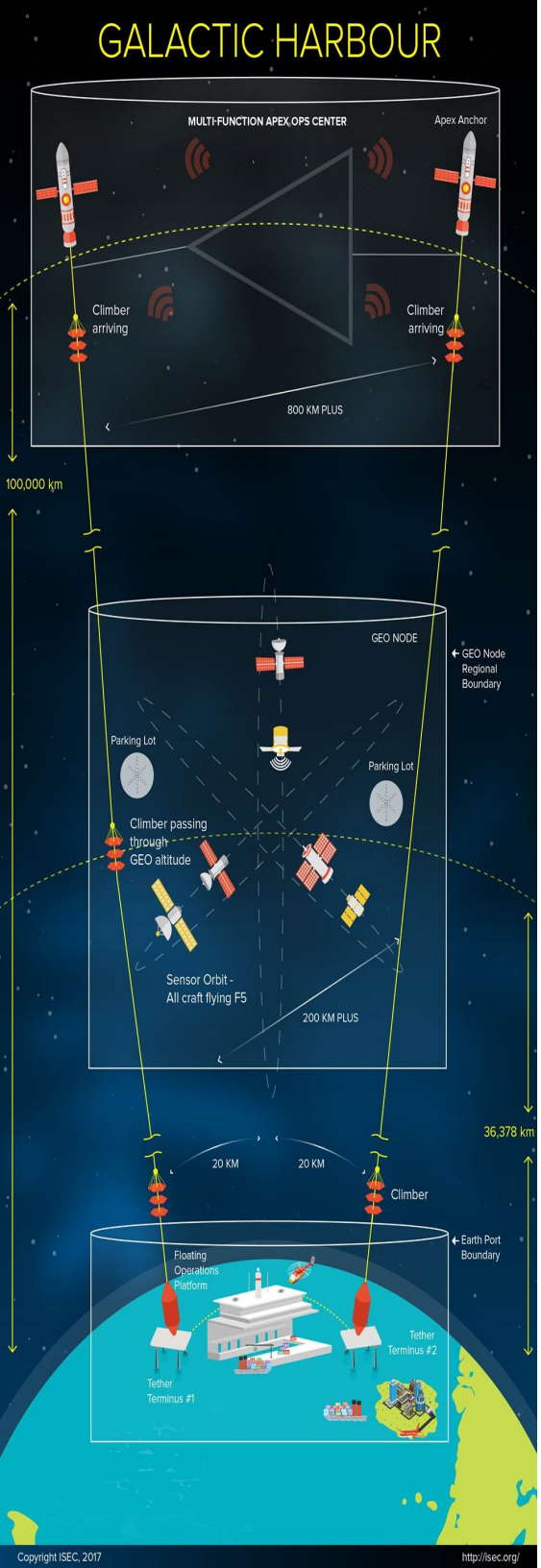


Dual Space Access Architecture
Advanced Rockets & Space Elevators
ISEC Webinar 24 July 2021

Peter A. Swan, Ph.D.

President and Member BoD, www.isec.org
International Space Elevator Consortium

Strategic Approach

Rockets to initiate Dreams of Many; while, Space Elevators move massive cargo as the Green Road to Space enabling these Dreams and Visions.

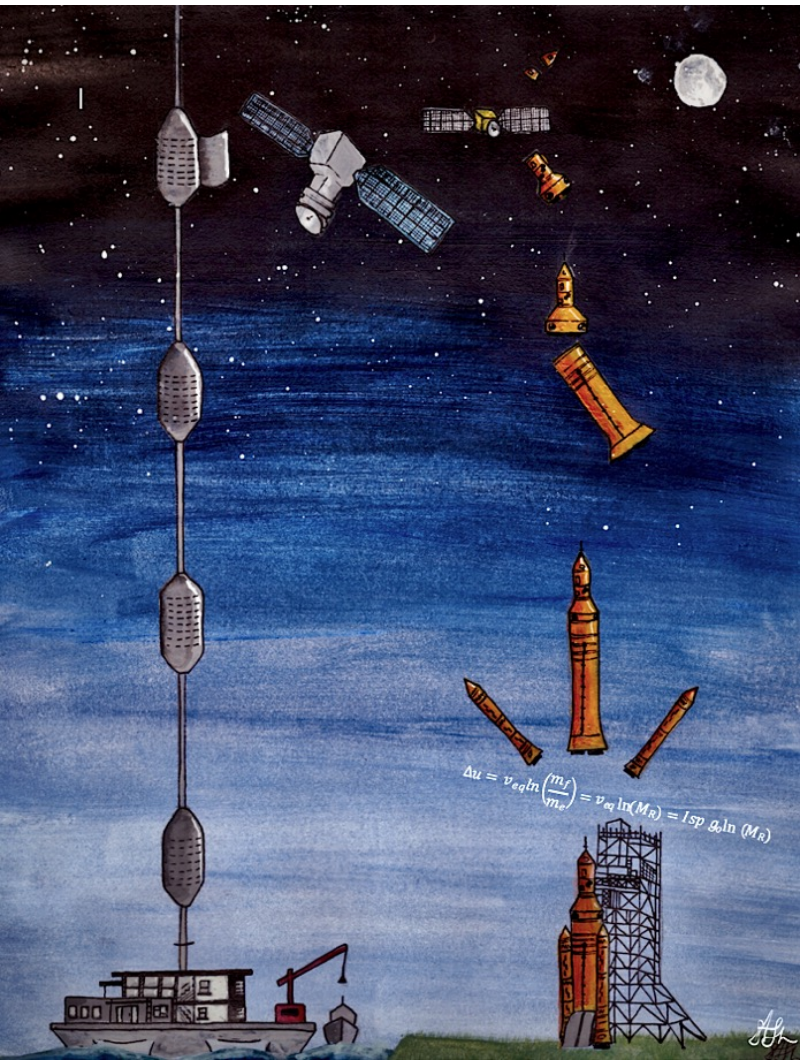
Dual Space Access Architecture
Advanced Rockets & Space Elevators

Discussion Today

- The future dreams and visions of so many around the world are expecting massive movement of cargo to support development. Mr. Musk, Mr. Bezos, Dr. Glaser, Dr. O'Neill, and the NSS
- Strengths of both approaches
- Dual Space Access applied to Space Solar Power
- Summary
- Questions

Strategy - Dual Space Access Architecture

Image by Amelia Stanton



Rocket Strengths: (1) Operational today with future growth, (2) rockets reach multiple orbits, and (3) rapid movement through the radiation belts

Space Elevator Strengths: As permanent infrastructure they lead to daily, routine, environmentally friendly, and inexpensive departures towards mission destinations

Combination of delivery approaches: Will greatly enhance the missions of the future. Maturing customer demand for huge masses to support important missions will make the value of space elevators obvious.

Dual Space Access: Minimizing the Rocket Equation Limitations

ISEC

7.76 km/sec

Apex Anchor

Tether

Geostationary Node

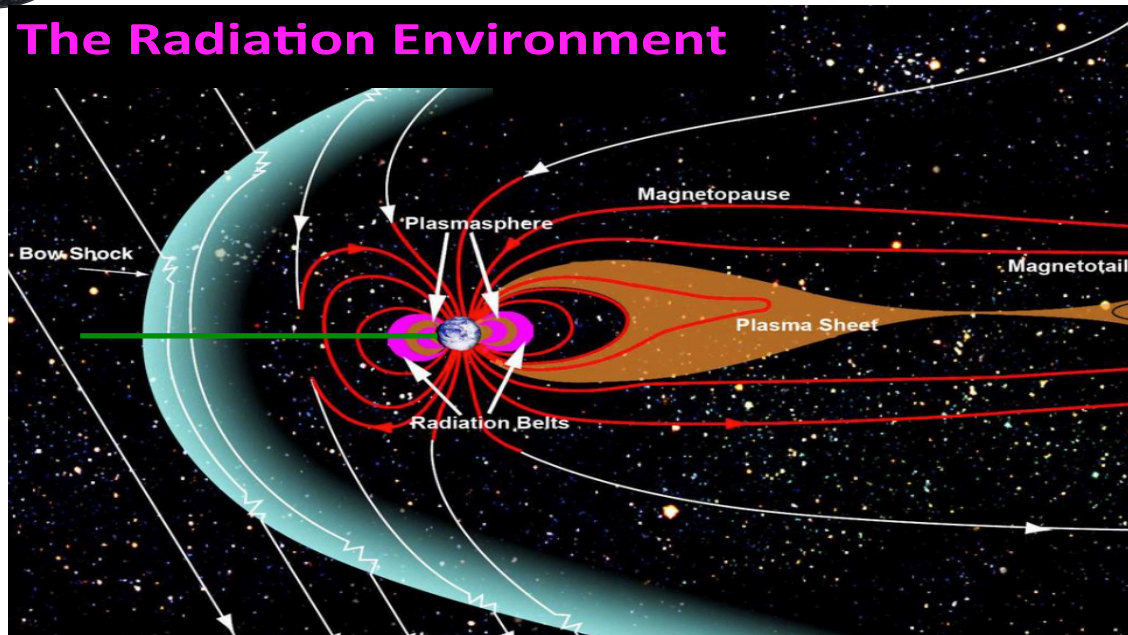
Climber

Marine Node

Diameter of earth 12,742 km

Tether length 100,000 km

The Space Elevator



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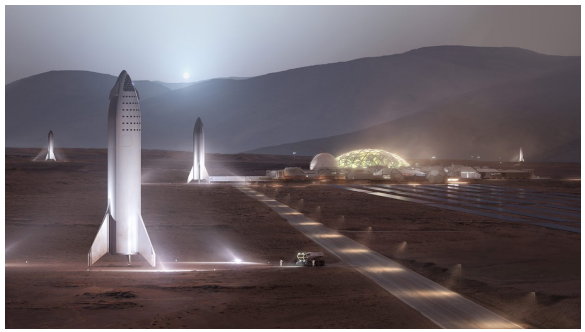
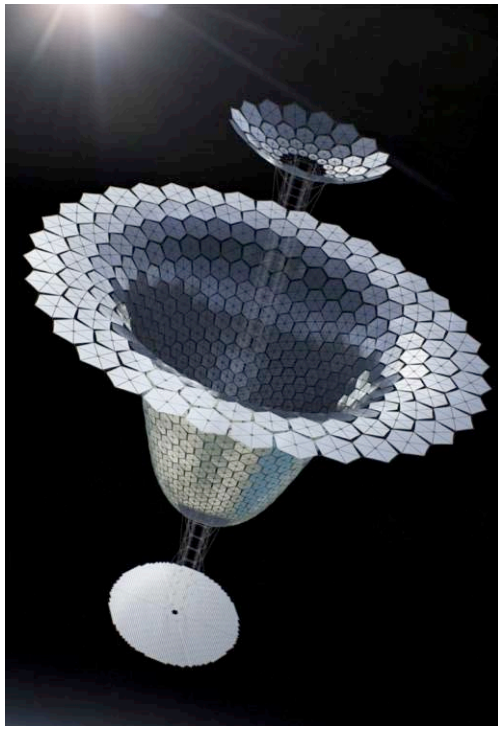
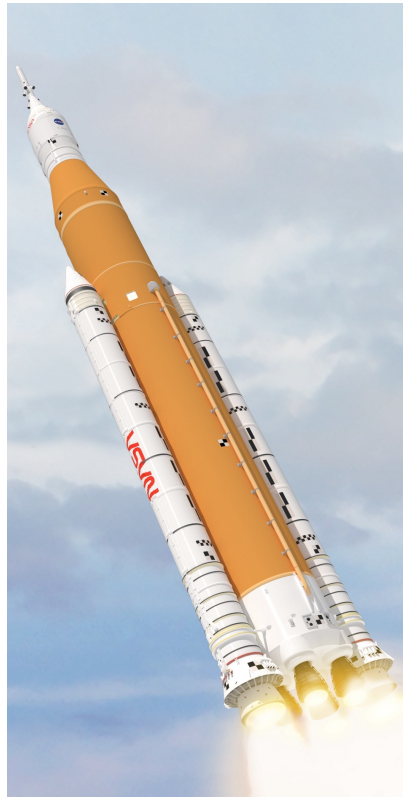
Accelerate American Space Leadership, Starting with Visions

- Millions of people living and working in space – Mr. Bezos (build the road to space)
- Making Humanity Multiplanetary – Mr. Musk
- First woman and next man on the Moon - NASA
- Living and working in thriving communities beyond Earth – NSS
- Stop Global Warming – Dr. John Mankins



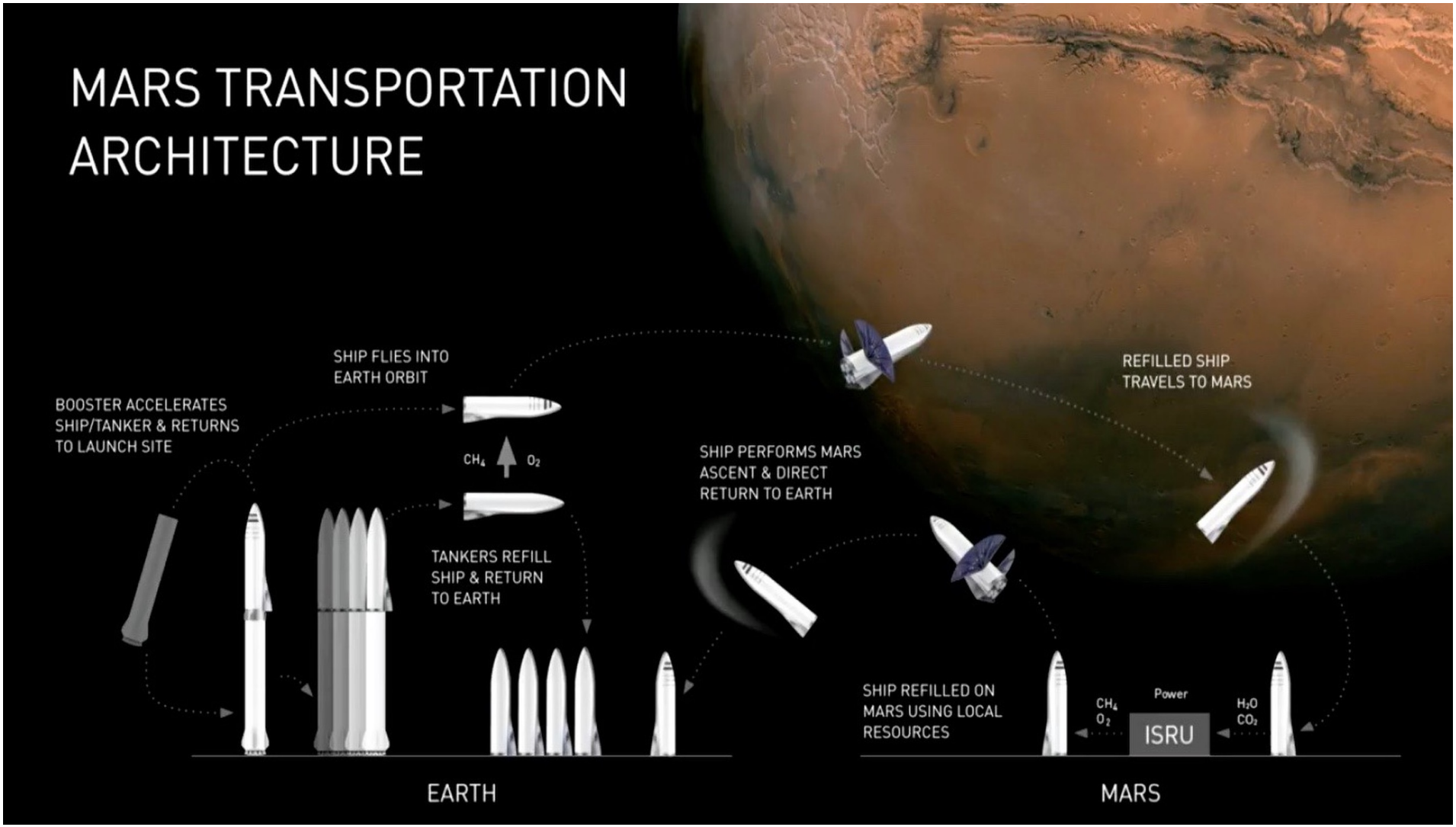




New Space Elevator Vision:

Space Elevators are the Green Road to Space while they enable humanity's most important missions by moving massive tonnage to GEO and beyond.

SpaceX Systems Approach to Mars



National Space Society Vision

- NSS Vision: “People living and working in thriving communities beyond the Earth, and the use of the vast resources of space for the dramatic betterment of humanity.”
- NSS Mission: “to promote social, economic, technological, and political change in order to expand civilization beyond Earth, to settle space and to use the resulting resources to build a hopeful and prosperous future for humanity.”

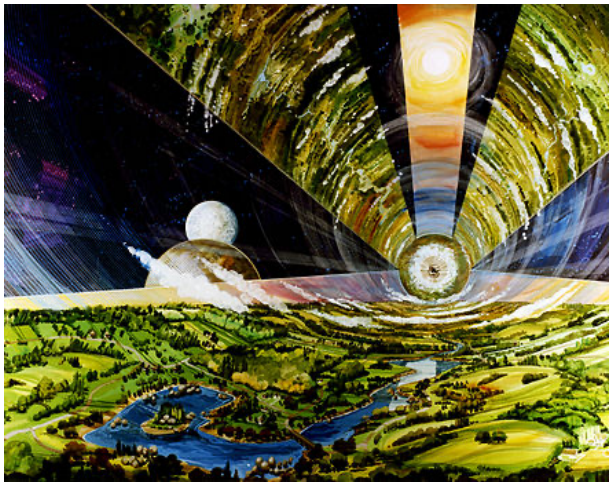
As the NSS merged from the National Space Institute and the L-5 Society, the vision is historic.

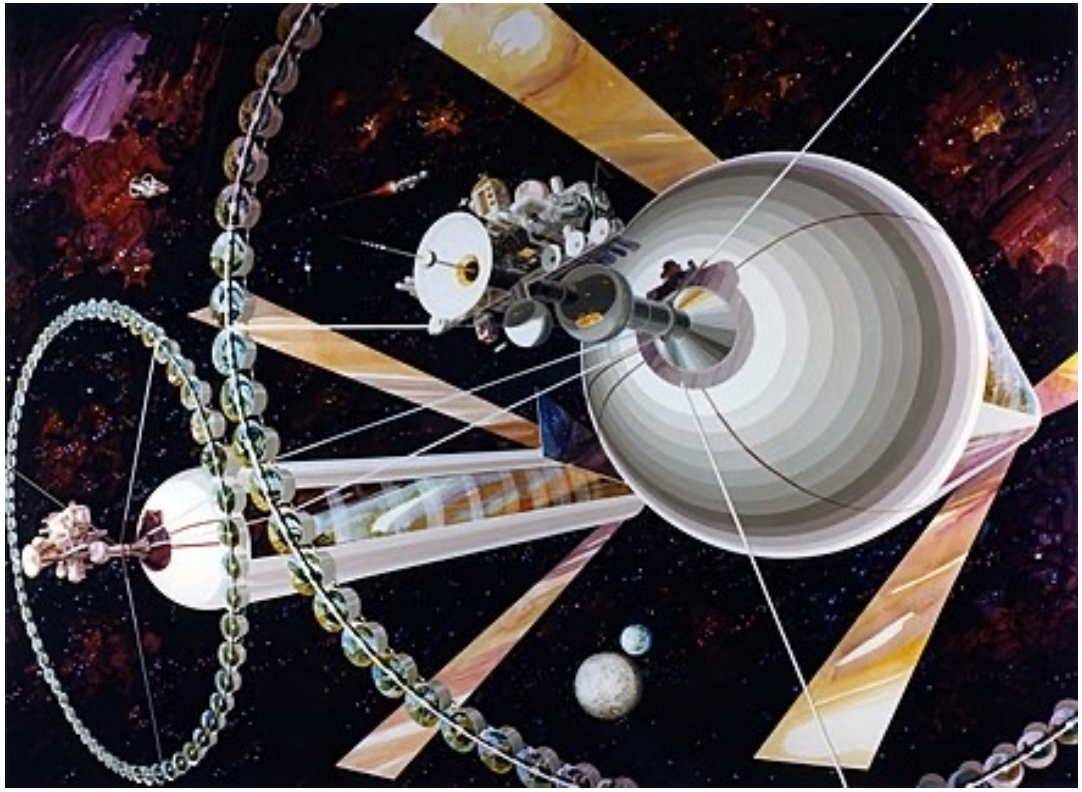
O'Neill's Vision

High-Frontier, Human Colonies in Space
Gerard K. O'Neill book in 1976 – Rotating Cylinders

His paper finally appeared in the September 1974 issue of *Physics Today*. In it, he argued that building space colonies would solve several important problems: It is important to realize the enormous power of the space-colonization technique. If we begin to use it soon enough, and if we employ it wisely, at least five of the most serious problems now facing the world can be solved without recourse to repression:

1. bringing every human being up to a living standard now enjoyed only by the most fortunate;
2. protecting the biosphere from damage caused by transportation and industrial pollution;
3. finding high quality living space for a world population that is doubling every 35 years;
4. finding clean, practical energy sources;
5. preventing overload of Earth's heat balance.



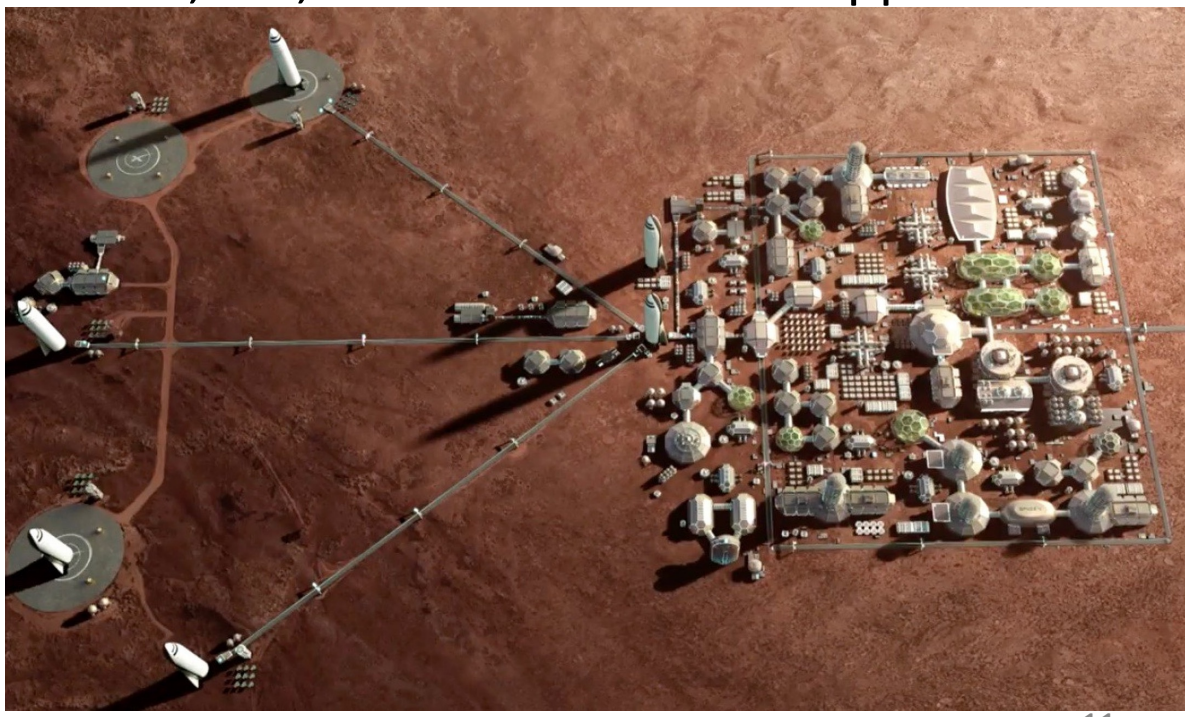


10,500,000 tonnes to L-5,
for several million people

Images by NASA and Rick Guidice

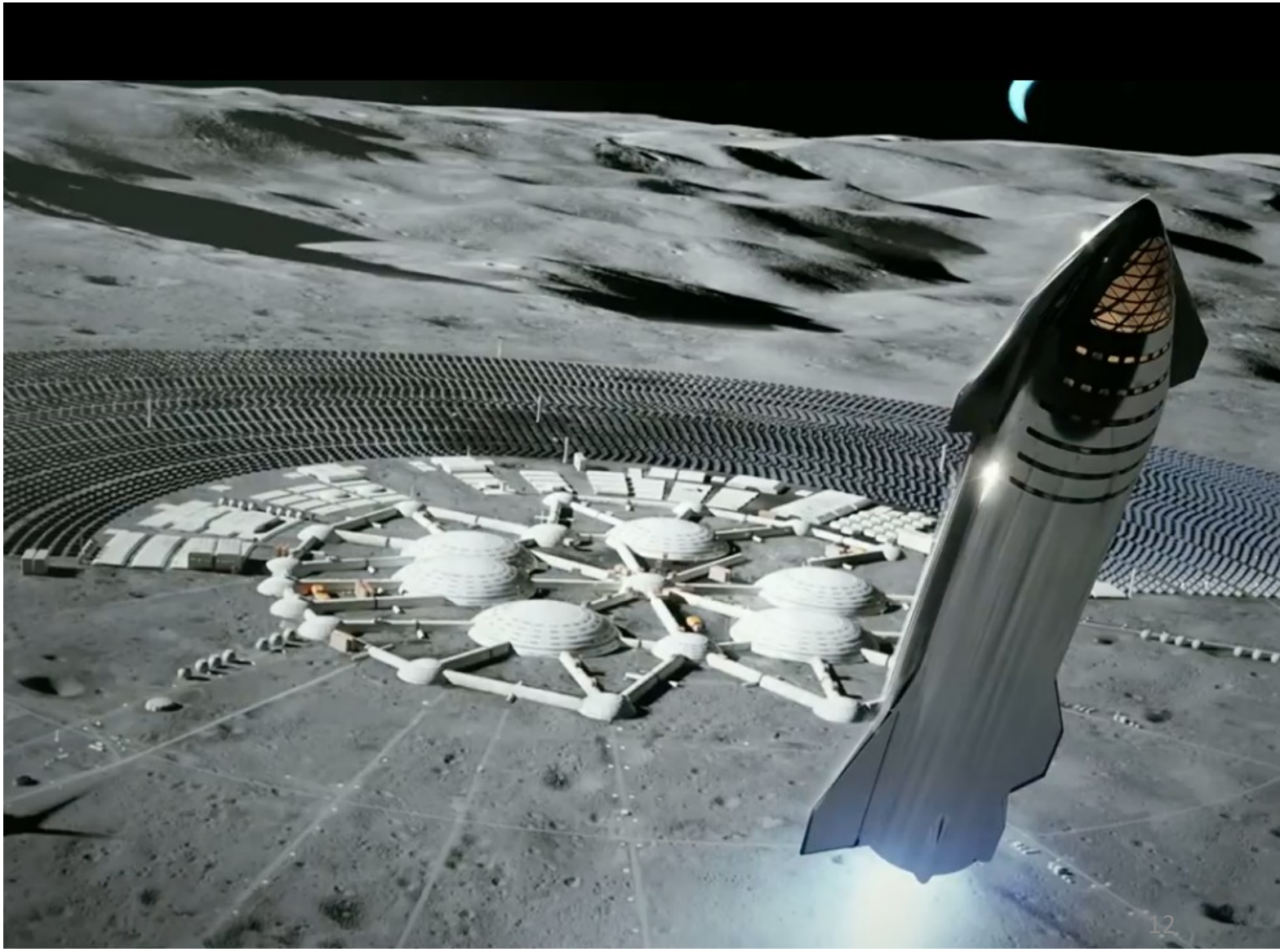
Mars Colony

- I think there are really two fundamental paths. History is going to bifurcate along two directions. One path is we stay on Earth forever, and then there will be some eventual extinction event. I do not have an immediate doomsday prophecy, but eventually, history suggests, there will be some doomsday event. The alternative is to become a space-faring civilization and a multi-planetary species…*
- Mr. Musk stated that he needs 1,000,000 Metric Tons of support for his Colony.**



*Musk, Elon, "Making Humans a multi-Planetary Species," New Space, Vol 5, No 2.
**Musk, Elon., Quotation from CBS's Sunday Morning Show, 21 July 2019.

Lunar Village

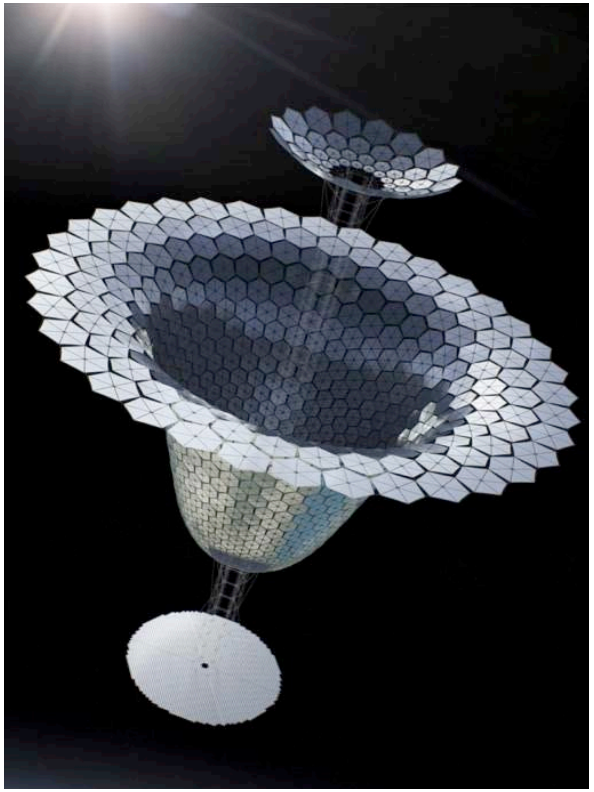


Estimate:
500,000 tonnes
To surface

Glaser's Vision
Space Solar Power

- "Space solar power can solve our energy and greenhouse gas emissions problems. Not just help, not just take a step in the right direction, but solve."
- Promise: Eliminate 100's (1,000's?) of Coal Burning Plants by providing 12% of 2060 Earth's population.
- "I need 5,000,000 tonnes."*

Mankins, John, The Case for Space Solar Power, Virginia Edition Publishing Co. Dec 2013.
*Private conversation with Dr. Peter Swan Oct 2019

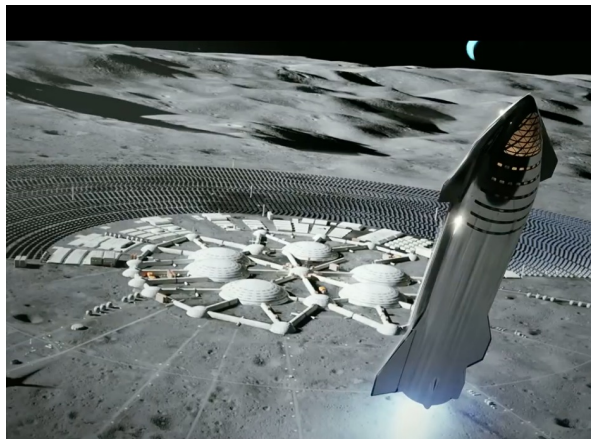


Each Alpha Mark IIA is 9,800 tonnes (to GEO)
For output of 2 Gwatt continuous

Key Question

I heard Dr O'Neal once say that our population in space could exceed that of Earth's. Do you believe that is possible?

What do you envision for Earth's future in space?



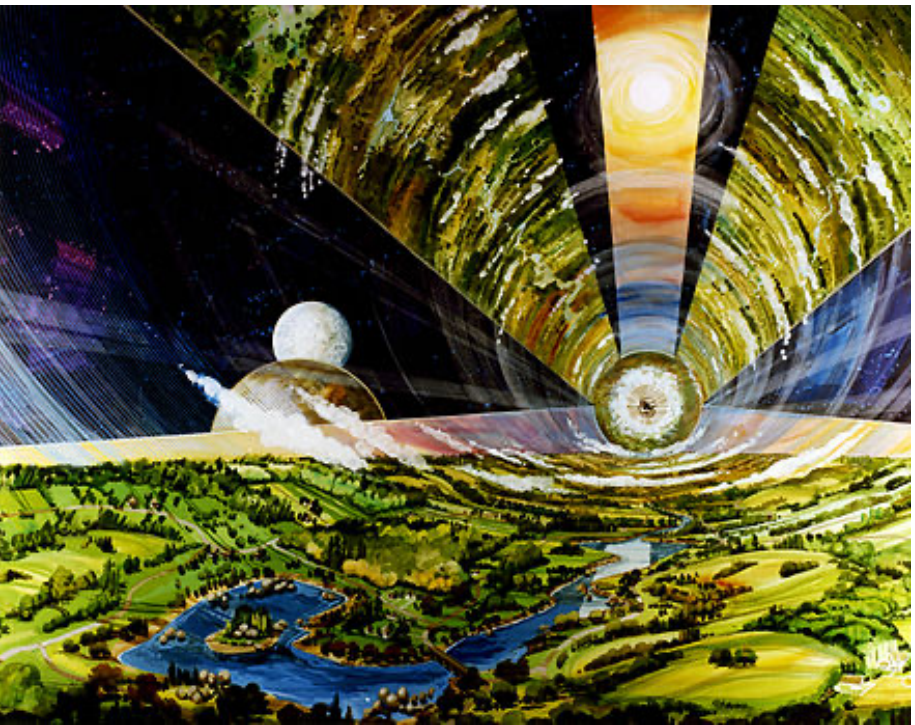


Image by NASA and Rick Guidice

SpaceX Images from web

Growth of Delivery Missions

- <u>Traditional Geosynchronous Orbit Missions</u>
- More and better traditional Satellites as access becomes easier and cheaper
  - Weather, communications, governmental missions
  - There are over 400 active GEO satellites (October 2018)
  - As the cost and simplicity of operations goes way down, this number will escalate.
- <u>Revolutionary Geosynchronous Orbit Missions</u>
- New missions will be supported
  - Refueling and repair of ailing satellites
  - Construction of new systems larger than a single payload
    - In a tether climber or rocket fairings
  - New enterprises not even thought of during the first three decades of this century.

Growth of Delivery Missions

- Revolutionary Geosynchronous Orbit Missions
- There will be huge growth when people realize the opportunities
  - Space Solar Power transmitting electrical power to Earth at low prices
- Lunar and Interplanetary Missions
  - Reference missions: Equipment and facilities to Moon Village and Mars Colony
- Robotic missions to anywhere in the solar system
- Missions to Lagrange-point colonies
- Robotic missions beyond the solar system

Customer Demand Pull

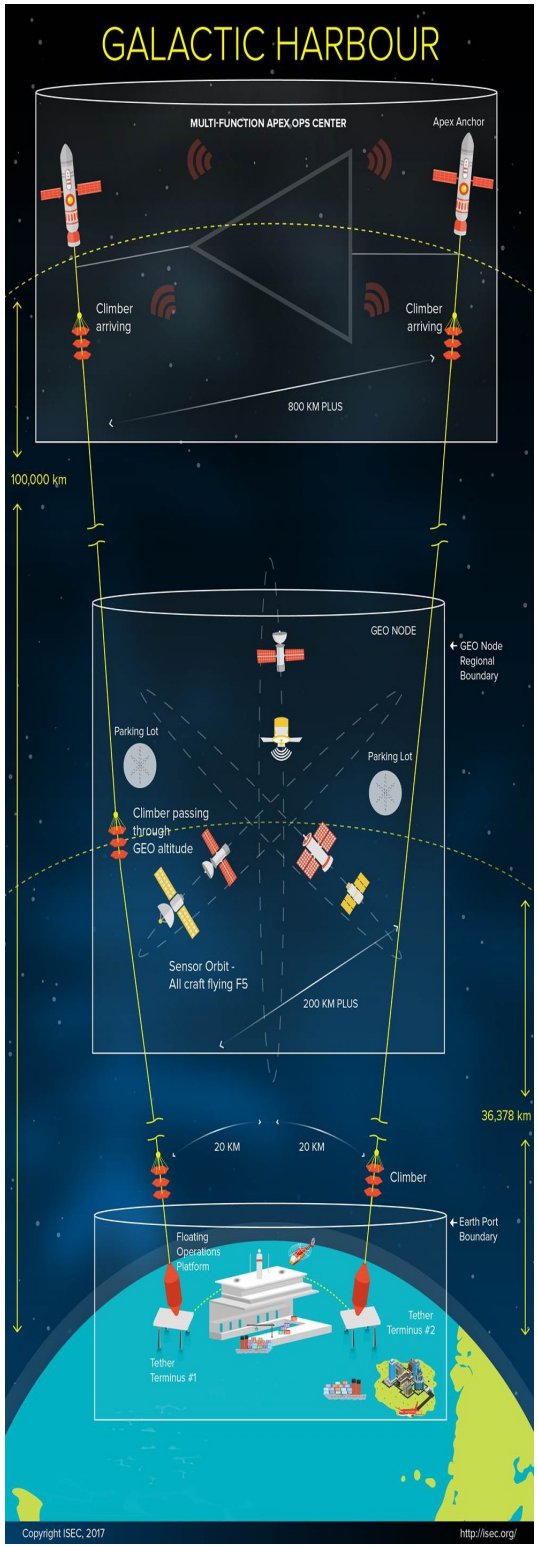
IAA Report 2013

Demand in Metric Tons	2031	2035	2040	2045
Space Solar Power	40,000	70,000	100,000	130,000
Nuclear Materials Disposal	12,000	18,000	24,000	30,000
Asteroid Mining	1,000	2,000	3,000	5,000
Interplanetary Flights	100	200	300	350
Innovative Missions to GEO	347	365	389	400
Colonization of Solar System	50	200	1,000	5,000
Marketing & Advertising	15	30	50	100
Sun Shades at L-1	5,000	10,000	5,000	3,000
Current GEO satellites + LEOs	347	365	389	400
Total Metric Tons per Year	58,859	101,160	134,128	174,250

Reference Missions:

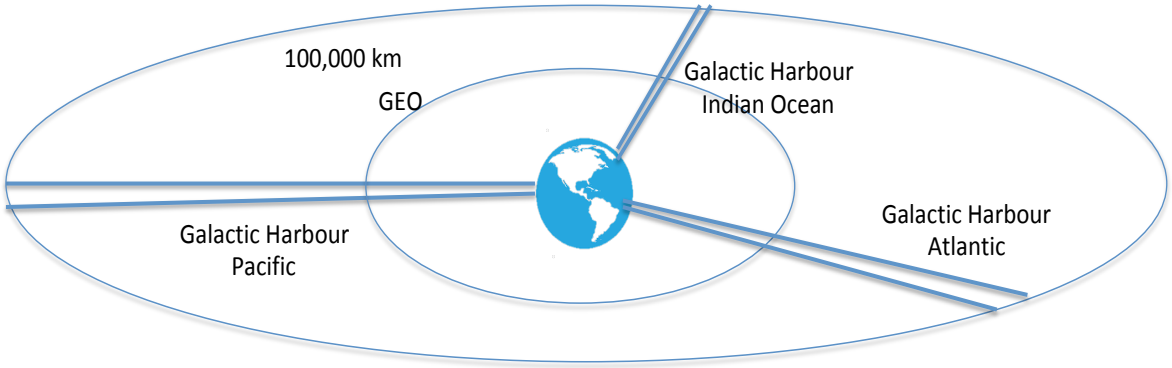
- Space Solar Power – 5,000,000 tonnes to GEO for 12% of Global Electrical need***
- Moon Village – 500,000 MT* - European "togetherness" towards a Moon Village suggests a massive support effort required.
- SpaceX Colony – 1,000,000 MT** – Mr. Musk has stated that he needs that amount of mission support on Mars.
- L-5 O'Neill Colony – 10,500,000 tonnes

* Estimate in Study Report "Space Elevators are the Transportation Story of the 21st Century
** Elon Musk, 21 July 2019, CBS Sunday Morning Interview
***Mankins, John, conversation with P. Swan



Pete's Vision of Galactic Harbours

A Green Road to Space



Massive tonnage raised by electricity to GEO and beyond, daily, routinely, inexpensively, safely, and in an Earth Friendly manner.

Three Galactic Harbours – Two Space Elevators each

Initially: 7 Climbers a week/SE – 14 MT each tether climber payload x2 x3 = 30,660 Tonnes/yr

Growing to: 7 Climbers a week/SE – 79 MT each tether climber payload x2 x3 = 173,010 Tonnes/yr

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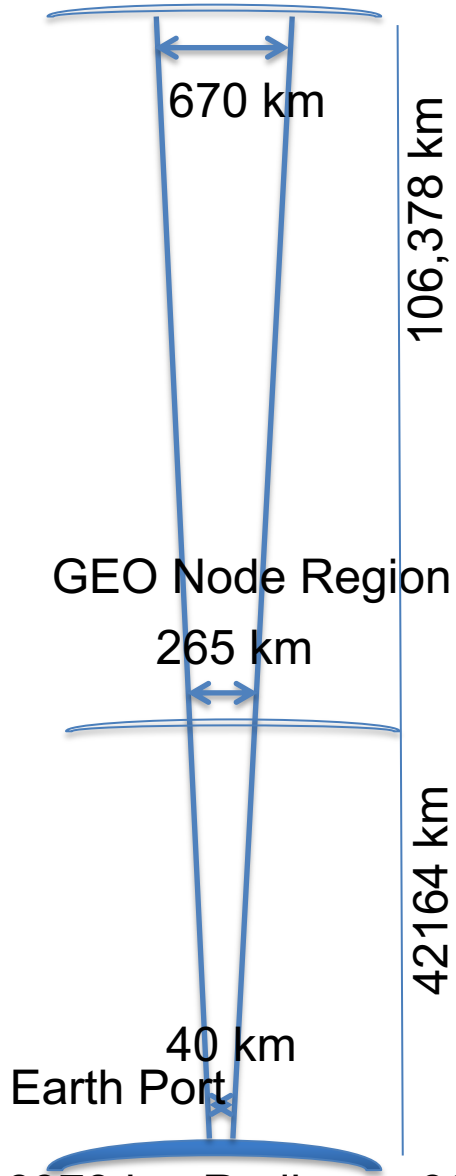
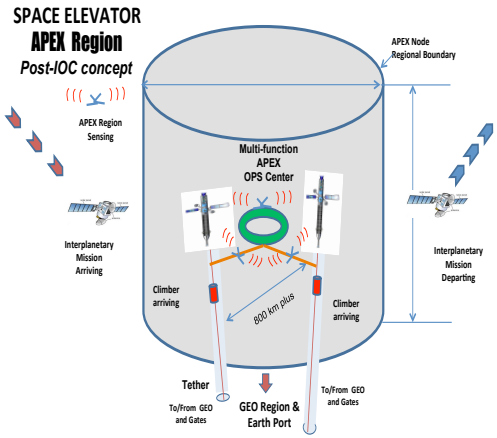
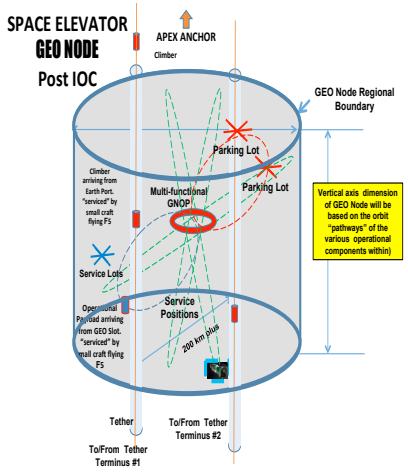
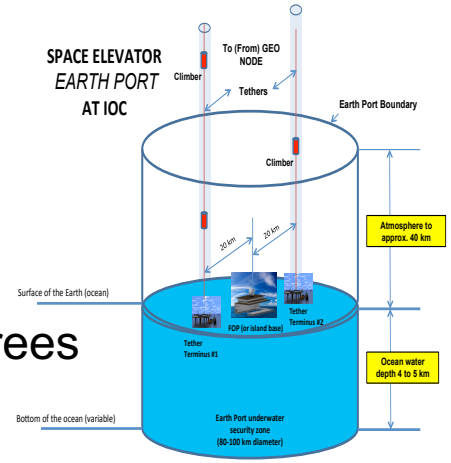








Our "strategy" is to link the Space Elevator Transportation System to the Space Elevator Enterprise; within a Unifying Vision

… the Galactic Harbour.

Characteristics

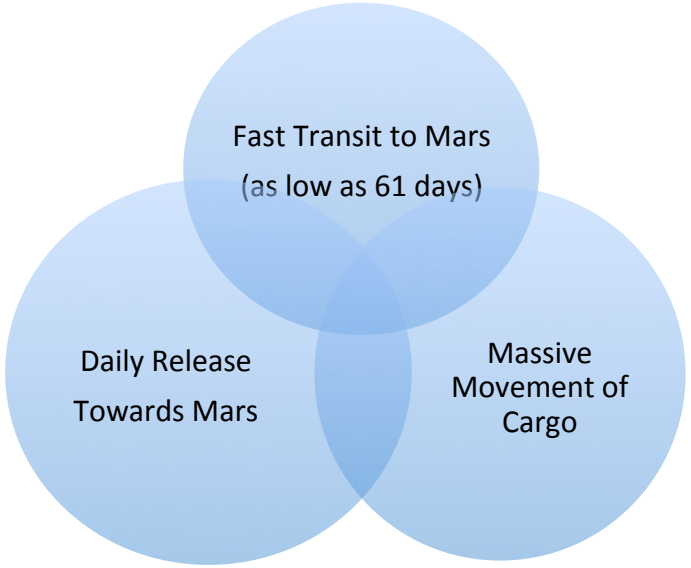
- Revolutionarily inexpensive to GEO [$100/kg to GEO]
- Commercial development similar to bridge building
- Routine [daily launches]
- Safe [no chemical explosions from propulsion]
- Permanent infrastructure 24/7/365/50 yrs. [bridge similarities]
- Massive loads with daily launches per elevator
- No shake-rattle-roll during launch
- “Big Green Machine” Little impact on global environment
- No consumption of fossil fuel.
- Does not leave space debris in orbit

Beats the Gravity Well in an environmentally friendly manner

Special Strengths for Mars

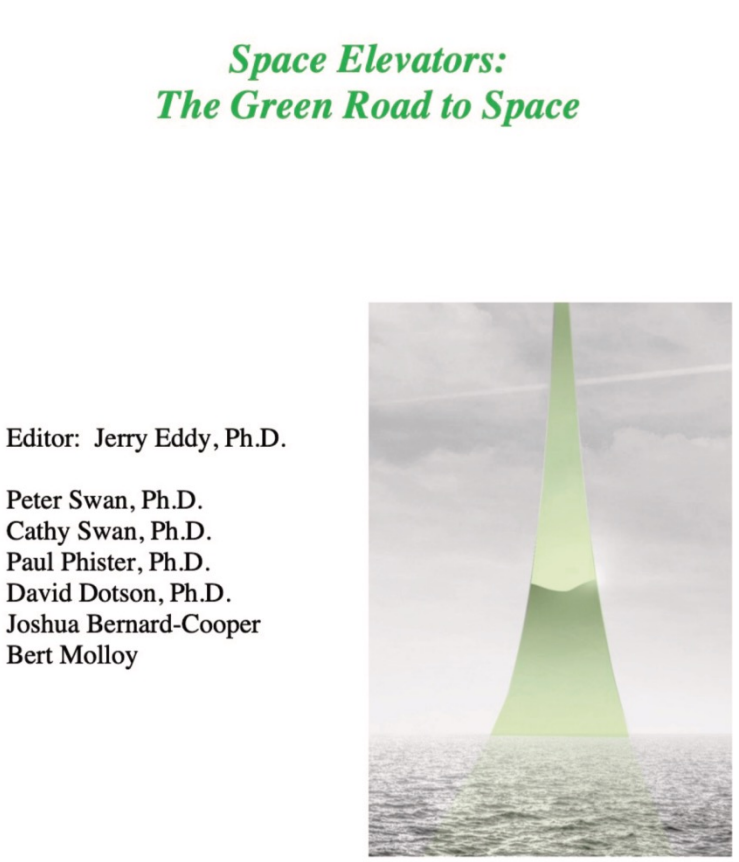
The unique characteristics of Space Elevators with a rapidly moving Apex Anchor (7.76 km/sec) enable remarkable opportunities for off-planet missions. This combination of three major strengths will ensure constant support to missions beyond Geosynchronous altitude. Strengths:

- Rapid Transit
  61 days
- Release daily
  365 opportunities each year
- Massive tonnes
  170,000 tonnes per year to GEO and Beyond

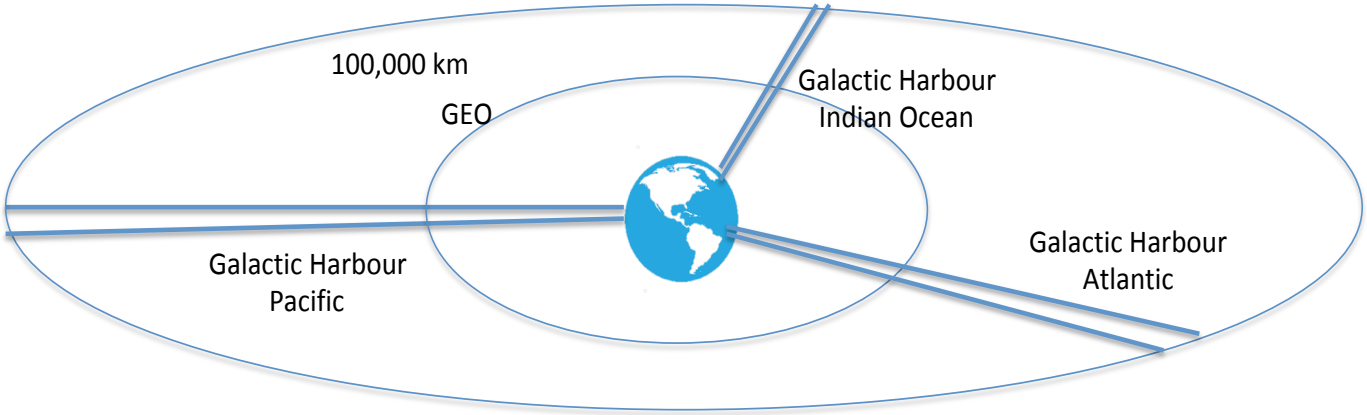


Space Elevators are the Green Road to Space

- 18-month study at www.isec.org (pdf free)
  - Electricity from the Sun's energy raises cargo from the ocean's surface to GEO
  - Massive cargo delivered to GEO and beyond enables Earth-friendly missions such as Space Solar Power
- A robust permanent transportation infrastructure
  - Moving more cargo in a year (25,000 tonnes) to GEO and beyond (at Initial Operational Capability) than humanity has placed in orbit since 1957 (22,000 tonnes)
- Enables Space Solar Power requires -- To supply 12% of the global electrical demand in 2060 while stopping global warming



Vision of Galactic Harbours – A Green Road to Space



Massive tonnage raised by electricity to GEO and beyond, daily, routinely, inexpensively, and safely

Three Galactic Harbours

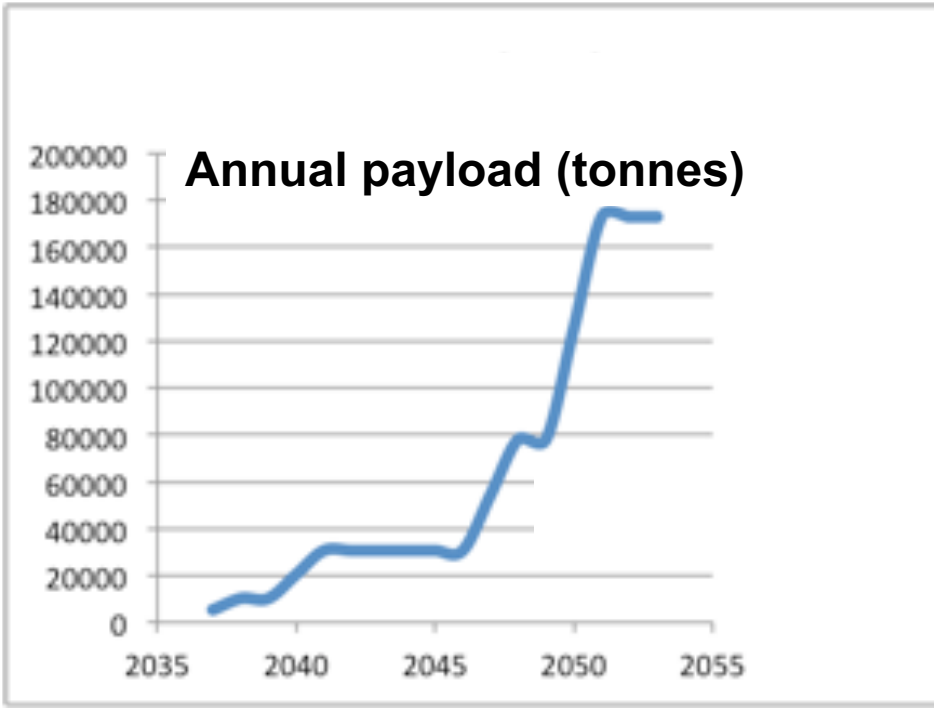
– 7 climbers a week/elevator

– 14 tonnes each, x2 x3

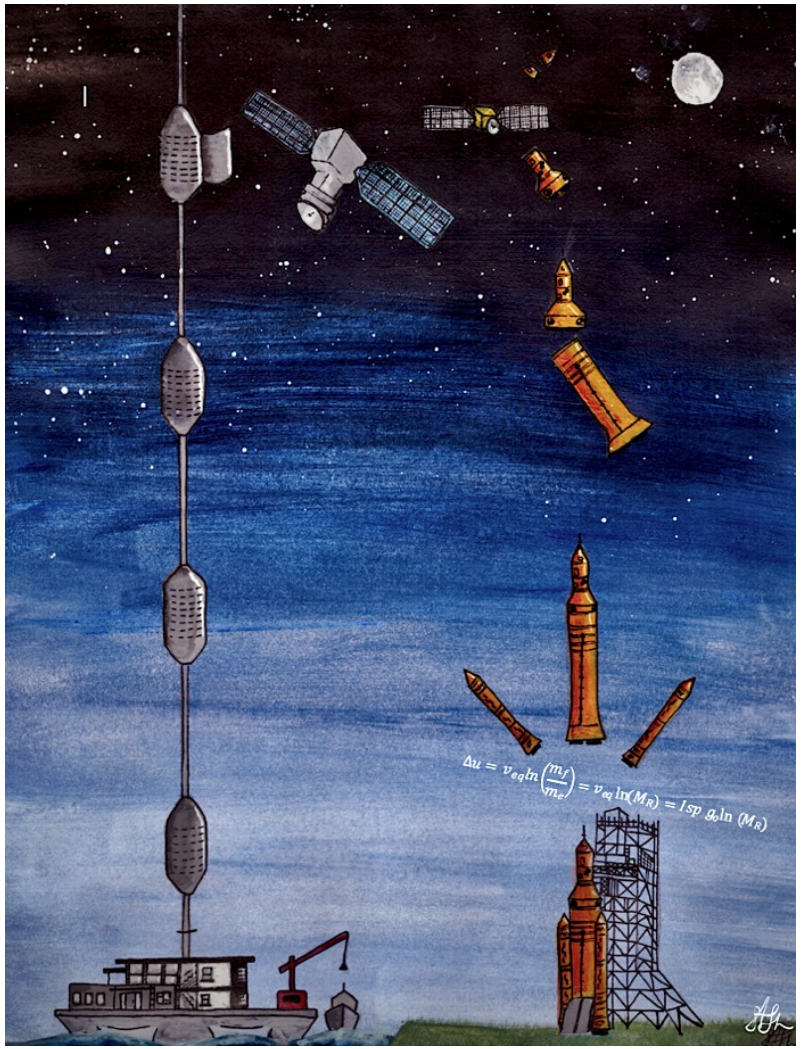
= 25,200 tonnes/yr

– expanding to 80 tonnes each

= 144,000 tonnes/yr



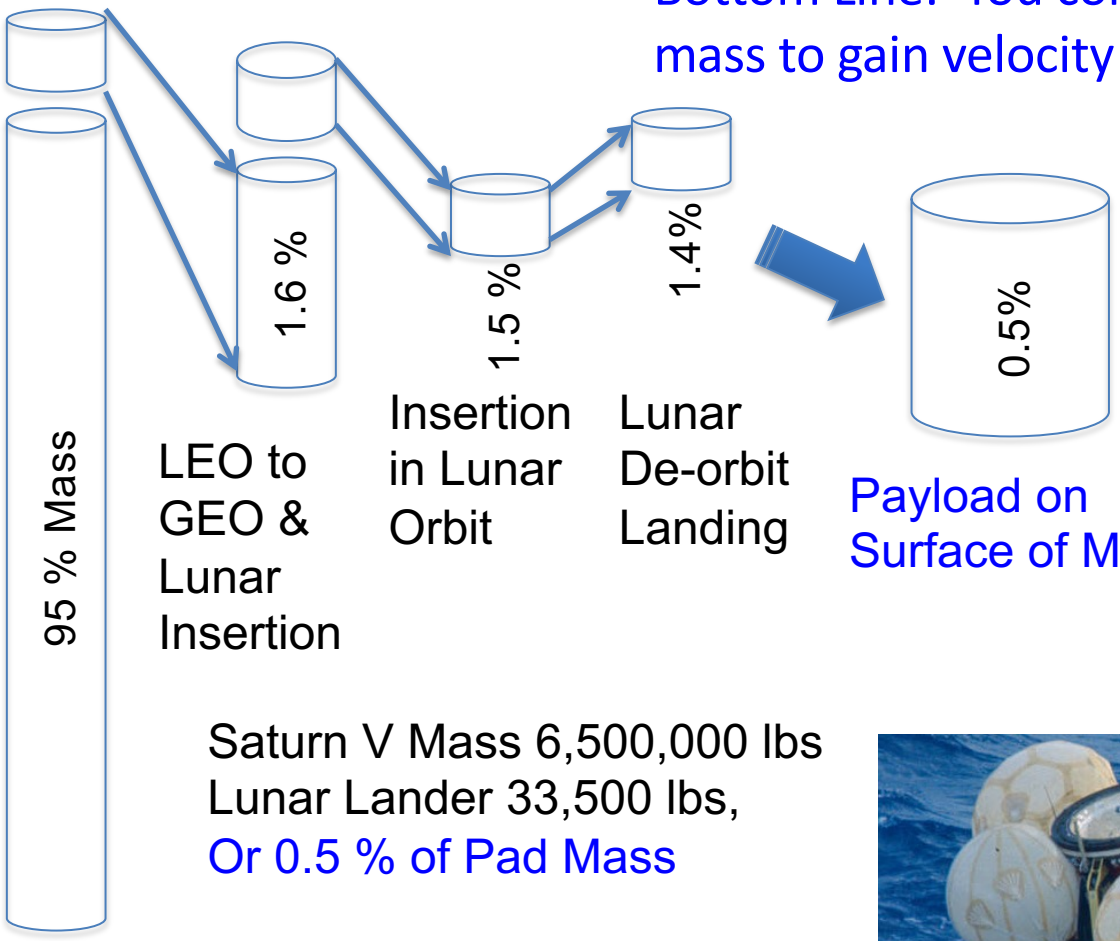
Why Space Elevators? Because we Must!



- Fulfills the Dreams of Many
- Raises Massive Cargo using Solar Energy
  - Green Road to Space
  - Permanent Infrastructure for GEO & Beyond
  - Daily, Routine, Safe, and Inexpensive
  - Early Operations: 30,000 tonnes per year
- Space Elevators are a Simple Elegant Solution to the Rocket Equation. - They avoid it!

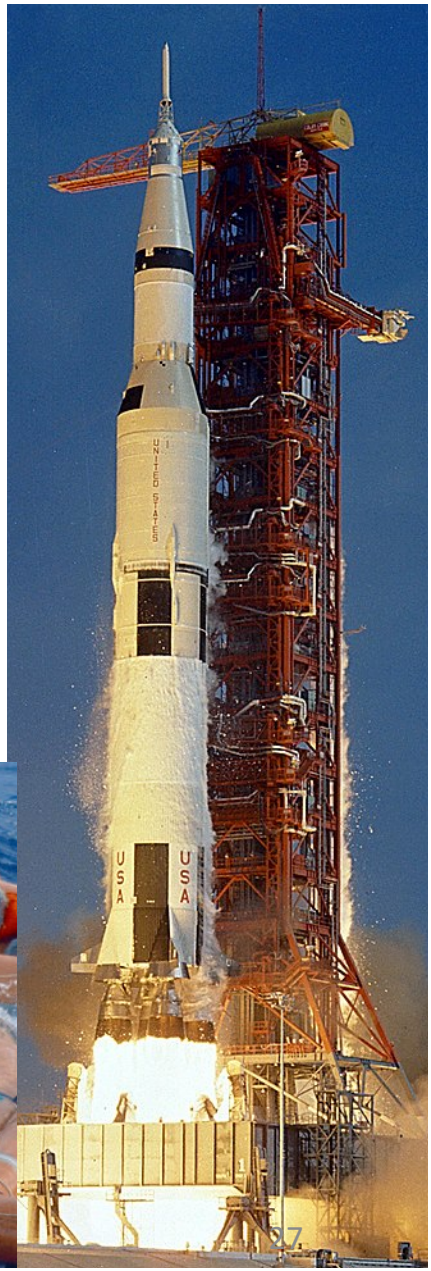
Rocket Equation an Example

Bottom Line: You consume your pad mass to gain velocity



Saturn V Mass 6,500,000 lbs
Lunar Lander 33,500 lbs,
Or 0.5 % of Pad Mass

$$\Delta v = v_e \ln \frac{m_0}{m_f} = I_{sp} g_0 \ln \frac{m_0}{m_f}$$



Conundrum of Rockets

Space Elevators answer the Conundrum of Rockets

The conundrum of rockets is the simple realization that the delivery of mass to its destination is an insignificant percentage of the mass on the launch pad. The glaring example is the delivery of a half percent of the launch pad mass to the surface of the moon for Apollo 11. It is up to 2% for delivery to Geosynchronous Orbit and woefully small for delivery to Mars' orbit, much less Mars' surface. The question is why would you employ a methodology for delivery that only delivers less than one percent to your desired location (lets say the future Gateway around the Moon). The Space Elevator solves that conundrum by delivering 70% of the mass at liftoff (the other 30% is the tether climber and will be reused repeatedly) to GEO and beyond by leveraging electricity.

Delivery statistics to GEO would be up from 2% of rocket pad mass to 70% by Space Elevators per event – also delivered in an Earth Friendly Manner

Percentage to Orbit by Rockets

Mission	*Launch Vehicle*	*Total Mass at Pad (kg)*	*Mass at LEO Orbit*	*% to LEO Orbit*	*Mass at GTO Orbit*	*% to GTO Orbit*	*Comment*
STS -	Space Transportation						Columbia is payload of STS note; $1.6 B / launch -
Columbia	System	2,041,000	80,700	0.040	2270	0.1	for GTO, ComSat in Shuttle bay
Spacecraft	StarShip	5,000,000	100,000	0.020	21000	0.4	Needs refueling to leave LEO, for GEO no refuel
	NEW Glenn	1,323,529	45,000	0.034	13000	1	
Apollo	Saturn V	3,233,256	140000	0.043	41000	1.3	Tli vs. GEO
	Saturn V	3,233,256		0.005			To lunar surface
	Saturn V	3,233,256		0.002			Returned to Earth's ocean
	CZ-5-522	630,000	20,000	0.032	11000	1.7	
	Atlas V	590,000	18,500	0.031	8700	1.5	
Spacecraft	Ariane 5	737,000	20,000	0.027	10000	1.4	
	Soyuz	310,000	7,000	0.023			
	Soyus 2-1b Fregat	308,000	8,500	0.028	3000	1	
	StarShip	4,000,000	100000	0.025	21000	0.5	Starship to GEO, no refueling
	Falcon Heavy	1,420,788	63800	0.045	26700	1.9	
			ave	0.032		1.5	

Remember, the rocket equation does NOT have factors for cost nor reusability. The reuse of rocket segments is remarkable and lowers cost and increases Efficiency…. But it does not deliver more mass to orbit as percentages.

Additional Information

Mission	*Launch Vehicle*	*Total Mass at Pad (kg)*	*Mass at LEO Orbit (kg)*	*% to LEO Orbit*	*Mass at GTO Orbit*	*% to GTO Orbit*	*Comment*
Mars Missions							
Hope to Mars 2020	HIIA	350,000			1,350	0.400	fuel optimum
Mars 2020	Atlas V-541	531,000			1,025	0.200	fuel optimum
Voyager 1	Tital	632,970			1,820	0.300	to Jupiter then out of solar system

Launch Vehicle	*Mass on Pad (kg)*	*Mass Delivery*	*%*
Apollo Saturn V	3,233,256	Lunar lander = 15,103	0.5
		ocean landing = 5,557	0.17
Chang'e 5	870,000	8,200 towards Moon	0.94
		3,800 Lunar landing	0.4
Atlas V	590,000	to GEO = 8,700	1.4
Falcon Heavy	1,420,788	to GEO = 26,700	1.9
Starship	4,000,000	to GEO = 21000	0.5
New Glenn	1,323,529	to GEO = 13,000	1

Pete's Assumptions
Rockets provide:
4% of launch pad mass to LEO
2% to GEO and beyond
1/2 % to Lunar Surface

Massive Movement

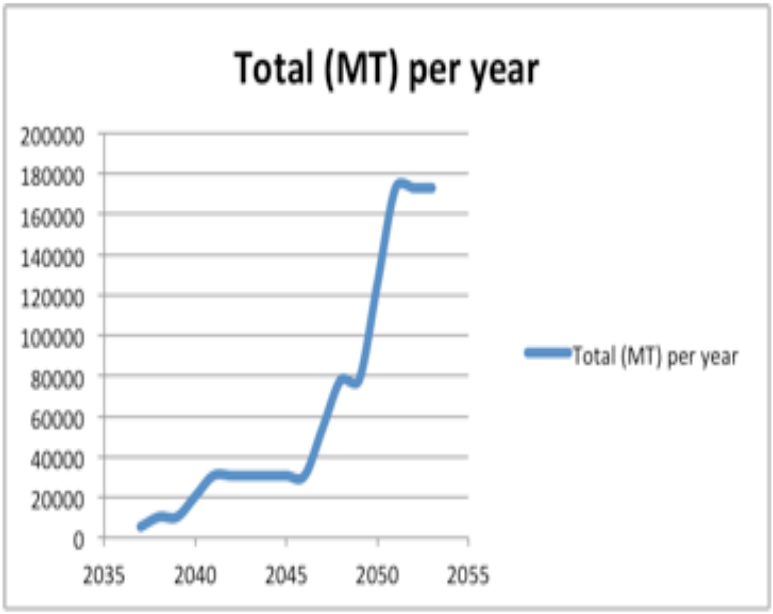
Type of Systems	*Orbit*	*Mass*	*Mass on pad*
		Tonnes	tonnes
Space Stations	LEO	431	10775
Earth Orbiting Sat's 2020	LEO, MEO, GEO	3220	80500
past satellites deorbited	LEO, MEO, GEO	1000	25000
Interplanetary	Solar System	100	5000
Lunar spacecraft	to the Moon	94	4700
Human to LEO	LEO	535	13375
Apollo Capsule to Moon	Lunar	336	16800
Space Shuttle*	LEO	16500	412500
Totals		22,216	568,650

Note: Leo is 4% of launch pad mass
GEO, Interplanetary, Lunar 2% of pad
*Shuttle launch vehicle reached orbit as an operational satellite

Historic Movement (1957 – 2020)

Result: 22,216 tonnes between 1957 and 2020.

Space Elevator expected movement of mass



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Advanced Rockets & Space Elevators

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Rockets to initiate Dreams of Many; while, Space Elevators move massive cargo as the Green Road to Space enabling these Dreams and Visions.

Discussion Today

- The future dreams and visions of so many around the world are expecting massive movement of cargo to support development. Mr. Musk, Mr. Bezos, Dr. Glaser, Dr. O'Neill, and the NSS
- Strengths of both approaches
- Dual Space Access applied to Space Solar Power
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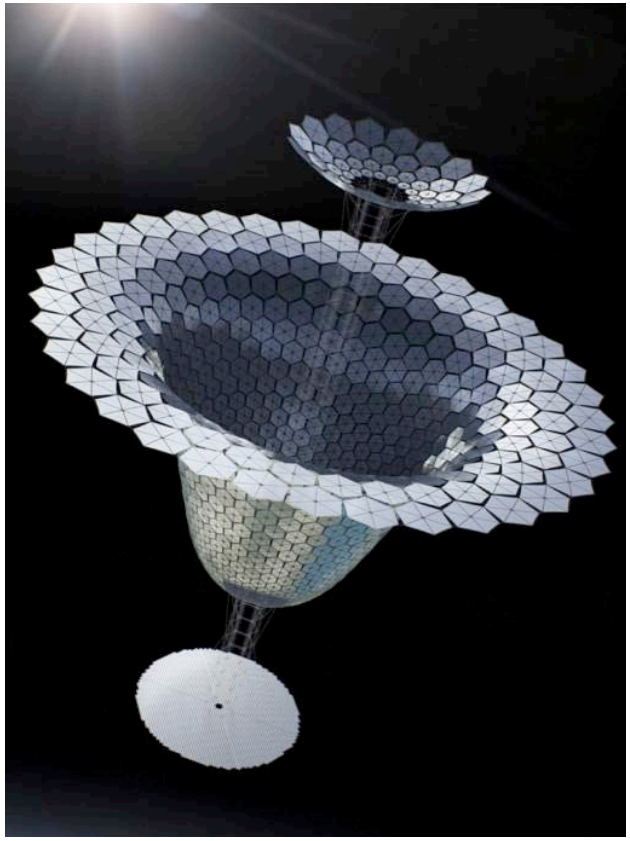
Space Solar Power

"Space solar power can solve our energy and greenhouse gas emissions problems. Not just help, not just take a step in the right direction, but solve."

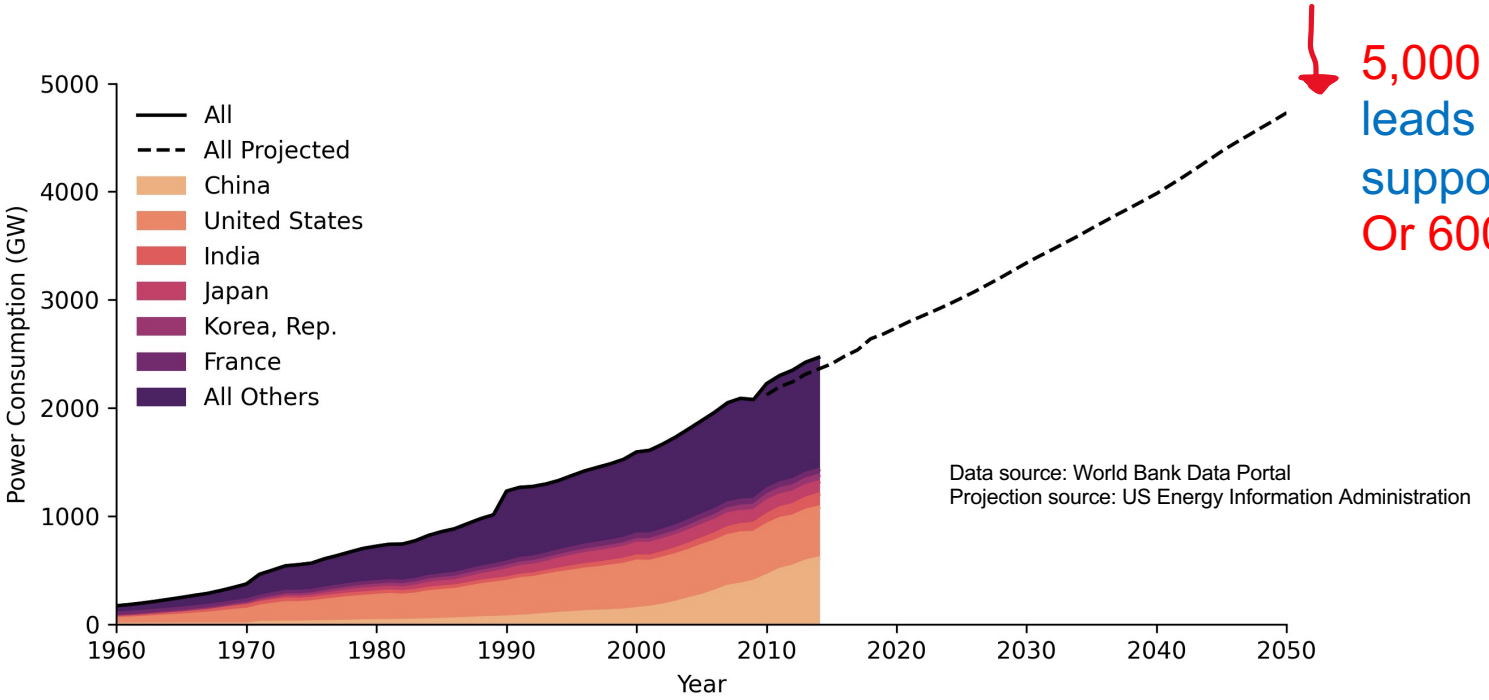
Eliminate 100's (1,000's?) of Coal Burning Plants by providing 12% of 2060 Earth's population.

Cost: Launching 5 million tons to GEO



Mankins, John, The Case for Space Solar Power, Virginia Edition Publishing Co. Dec 2013.

Electricity demand is rising globally



By 2050, global electricity demand will nearly double from 2,467 GW in 2014 to 4,730 GW by 2050

- Non-OECD countries driving most of this growth, in particular China and India
- Electrification of transportation in the U.S. expected to be a driver of growth domestically

Opportunity exists for powering U.S. cities

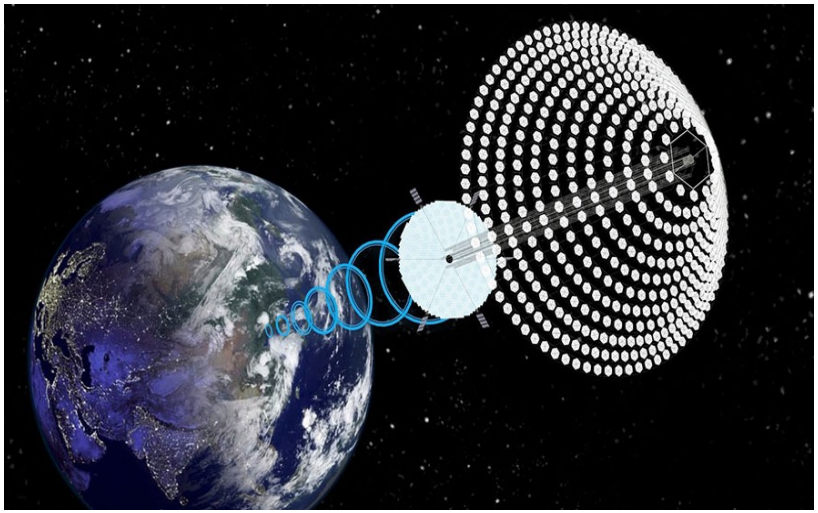
SPS-ALPHA Mk-II systems can meet today's typical power requirements for:

- New York City with a trio
- Houston or Los Angeles with a pair
- Chicago or Phoenix with a single system

Table: number of vehicles needed to satisfy demand in each city

	SunTower	CASSIOPeiA	Tethered SPS	SPS-ALPHA	OMEGA	SPS-ALPHA Mk-II	Reference System
New York	19.4	11.3	6.5	2.4	2.4	2.4	1.0
Houston	14.4	8.4	4.8	1.8	1.8	1.8	0.7
Los Angeles	10.8	6.3	3.6	1.3	1.3	1.3	0.5
Chicago	8.6	5.0	2.9	1.1	1.1	1.1	0.4
Phoenix	7.3	4.2	2.4	0.9	0.9	0.9	0.4

But mass-to-orbit is a major barrier



Source: John C. Mankins – SPS-ALPHA Mk-II

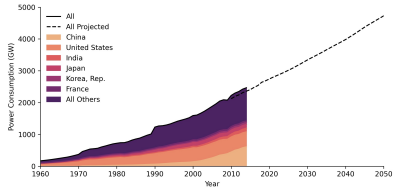
SPS-ALPHA Mk-II

- 2 GW of continuous power
- 2.45 GHz transmission
- 28.3 km^2 ground receiver
- **9,200 tonnes in orbit at GEO** (36,000 km altitude)

For a 2 GW SPS-ALPHA Mk-II system, 9,200 tonnes must be delivered to GEO

- This is 460 launches of a 20-tonne payload to GEO
- Possible in the next decade with launch schedules pursued by SpaceX, Blue Origin, and others

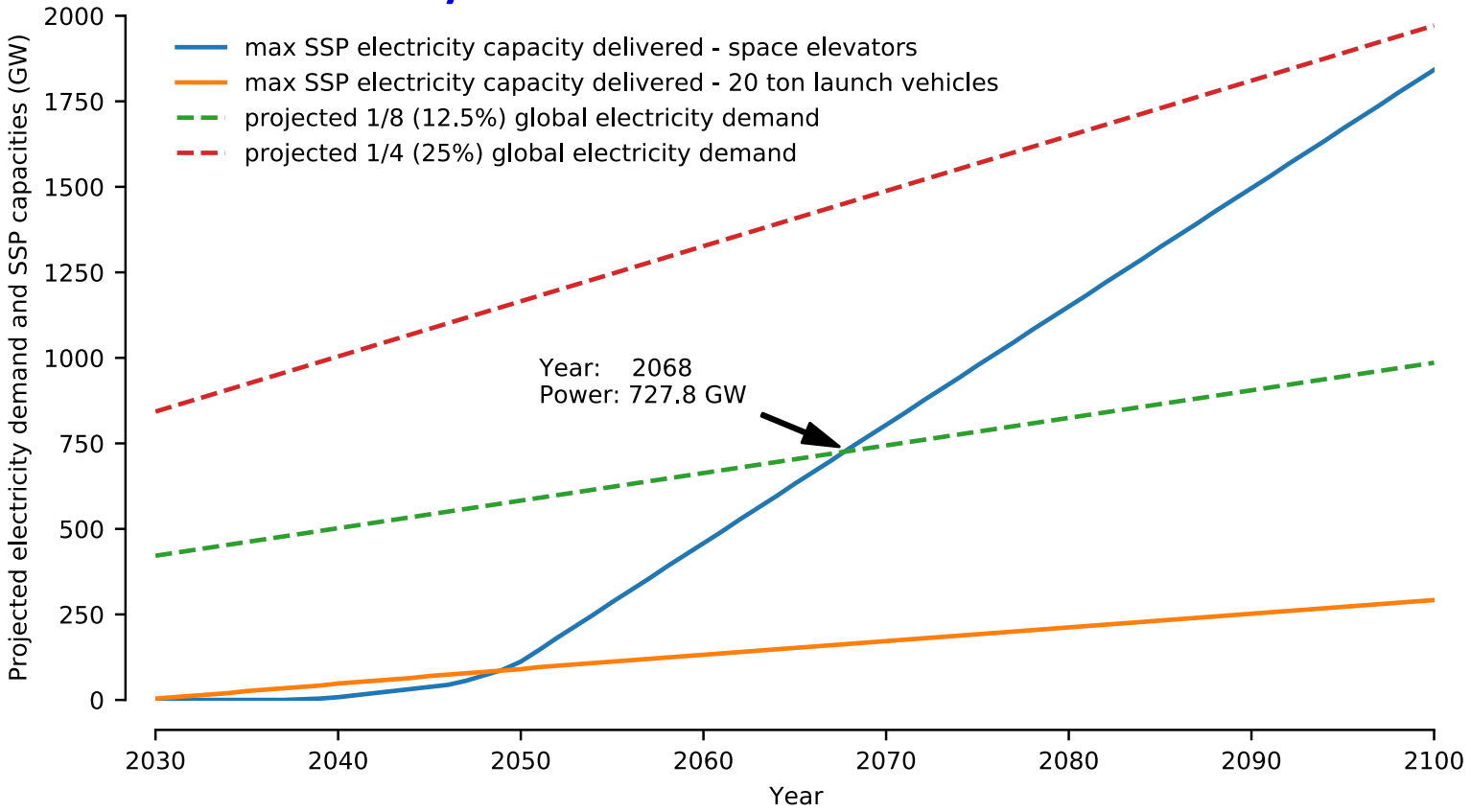
SSP to meet future global electricity demand



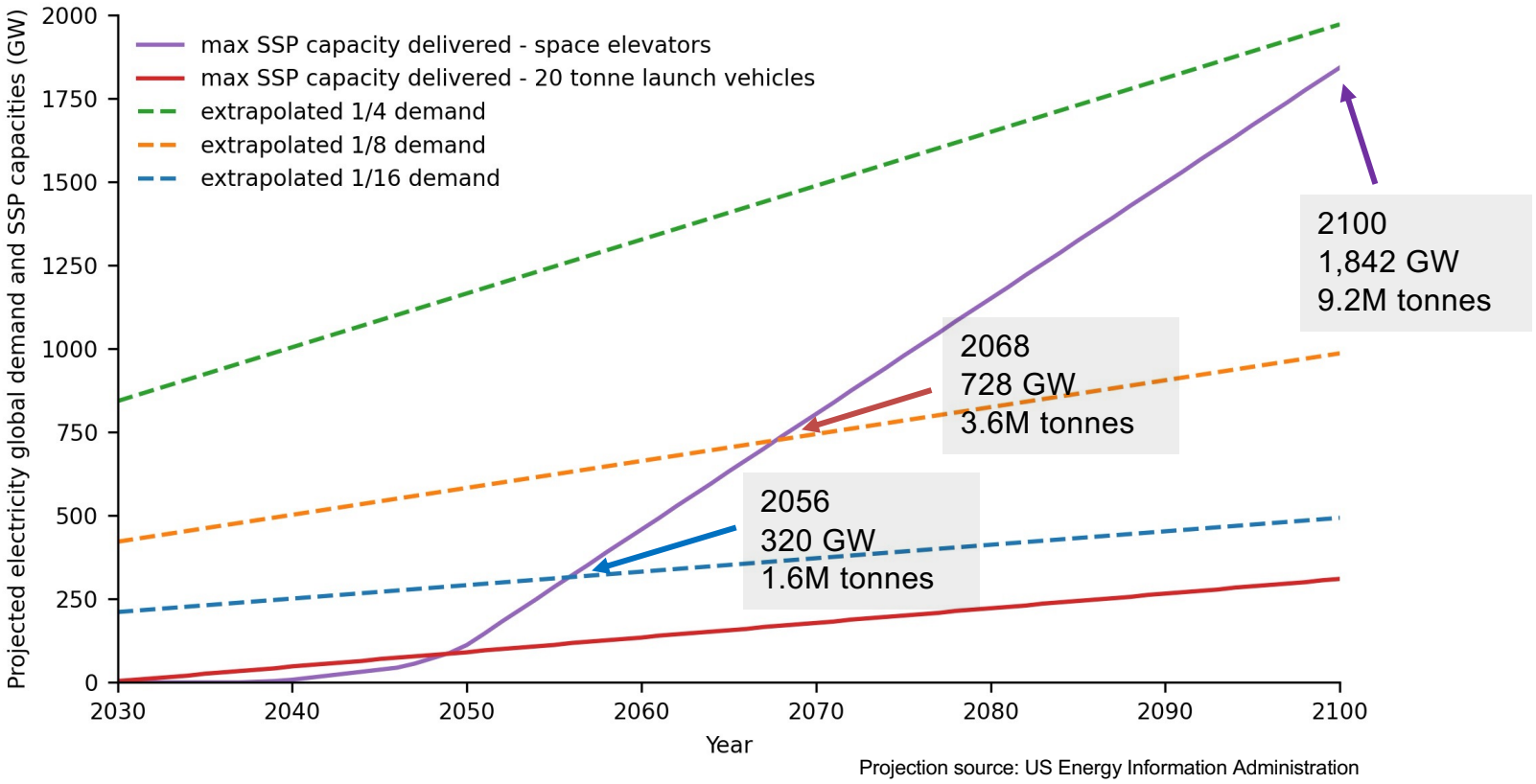
Solar Power Satellites

- Dr. Mankin's Goal is Green (12% global electrical demand by 2060 > 3,500,000 tonnes to GEO)
- Blue line is Space Elevator Capability

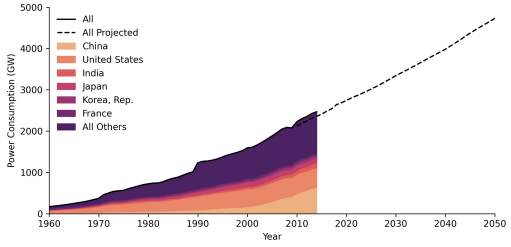
  Meet 727.8 GW by 2068



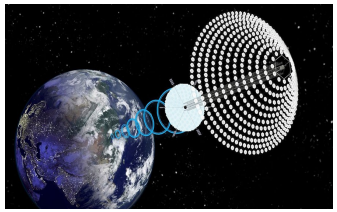
Meeting future global electricity demand with SSP



SSP Delivery Demands



- In 2060, 600 GW electrical energy to surface



- Alpha IIA at 2 GW goes to 300 satellites, each at 9,200 tonnes or 2,760,000 tonnes to GEO

- Starship, 20 tonnes to GEO per launch, or 138,000 launches – at 1,000 per year – 138 years.

Dual Space Access Architecture
Advanced Rockets & Space Elevators

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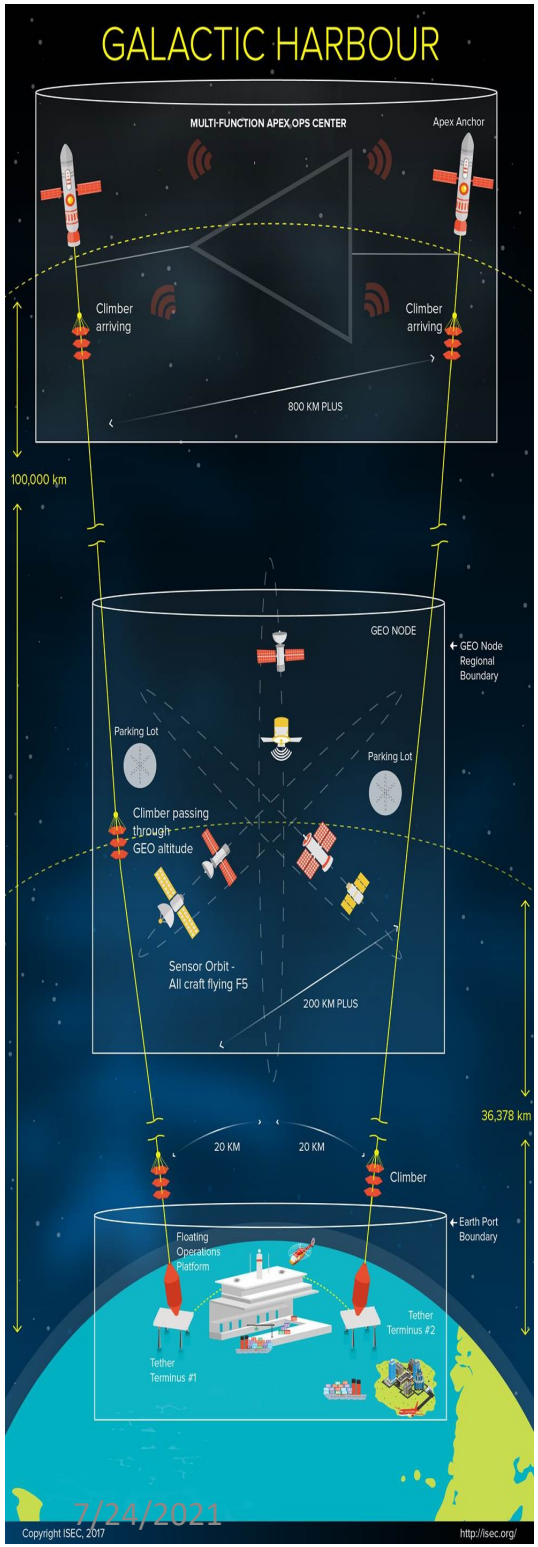


Simple Elegant Solution to the Rocket Equation. - They avoid it!

- Space Elevators Fulfill the Dreams of Many
- Space Elevators Raise Massive Cargo using Solar Energy
  - Green Road to Space (carbon negative in construction and operations – provides zero emissions for lift-off)
  - Permanent Infrastructure for GEO & Beyond
  - Daily, Routine, Safe, and Inexpensive
  - Early Operations: 30,000 tonnes per year, initially

Permanent Space Infrastructure (2030 +)

Strategy: Develop Commercial and Government programs advancing the new capabilities of reusability and rapid liftoffs.

Approach: A permanent Dual Space Access Architecture relies on Space Elevator traditional strengths such as inexpensive, safe, daily, routine, with special characteristic of Earth friendly, and its ability to avoid the rocket equation. The rockets are complementary and cooperative to Space Elevators and move people through radiation rapidly.

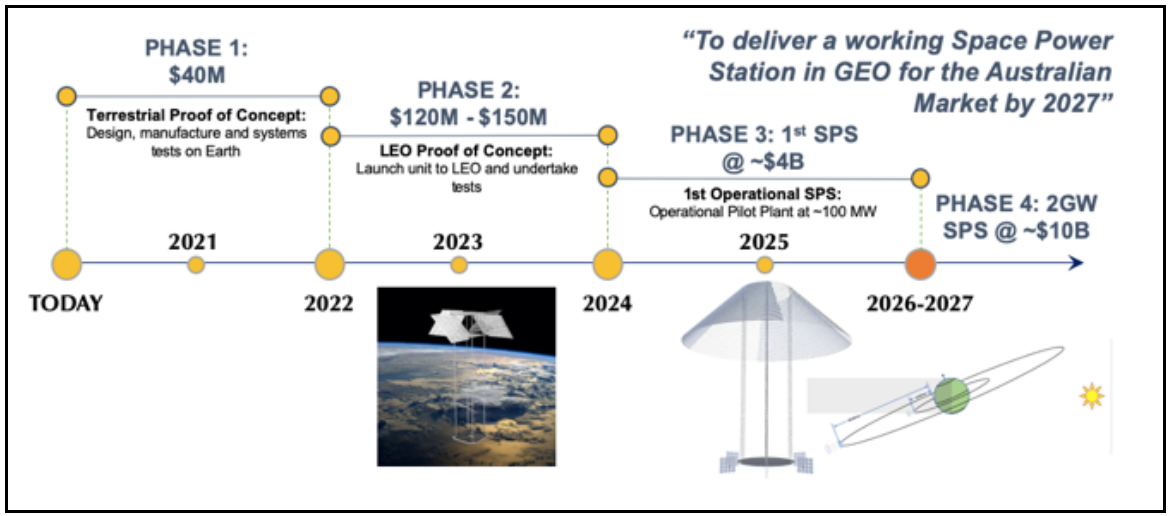
Result: A permanent dual infrastructure expanding with tremendous growth in jobs across the spectrum from manufacture to academia.

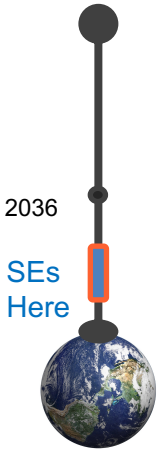
Rockets to Open up the Moon and Mars with Space Elevators to supply and grow the colonies.

Rockets to initiate SSP's prototypes with Space Elevators to supply and grow the Constellation.

Likely and possible for rockets to deploy the first SPS systems.

- Incredibly useful earth-to-orbit systems for deploying new space technologies, opening up new activities
- Deliver the initial prototypes to LEO for testing and the initial GEO production satellites for operational testing.





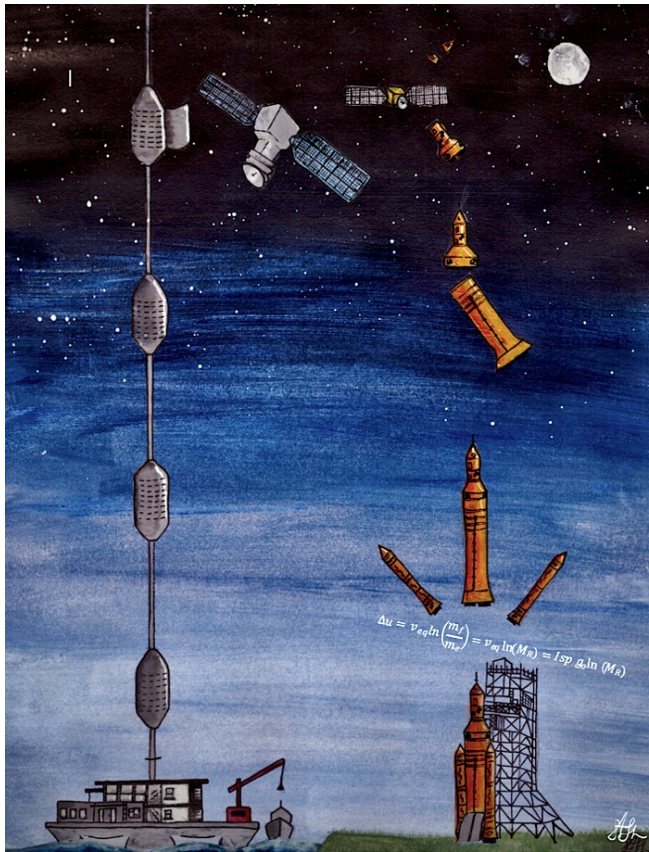
Space elevators are needed for high-throughput, massive hardware deployment.

- Consistent, continuous movement of freight to GEO and beyond
- Enable space technology deployment at scale for high impact
- Fills out the constellations by moving massive amounts of cargo

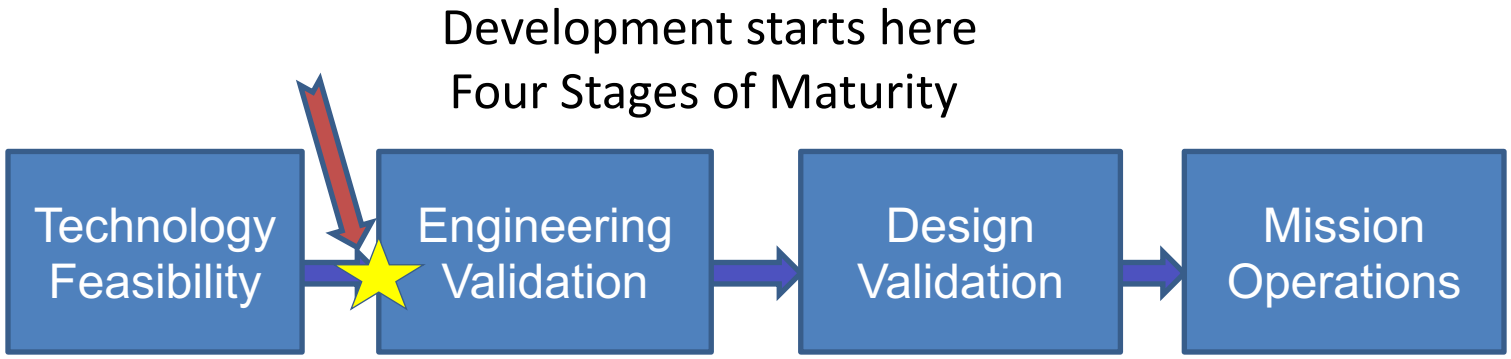
First Step Soon

- Galactic Harbours are the next evolutionary step for Humankind, and we can take that first step soon

- Dual Space Access Architecture is the Space Infrastructure Strategy of the future - a cooperative approach leveraging both rockets and space elevators.



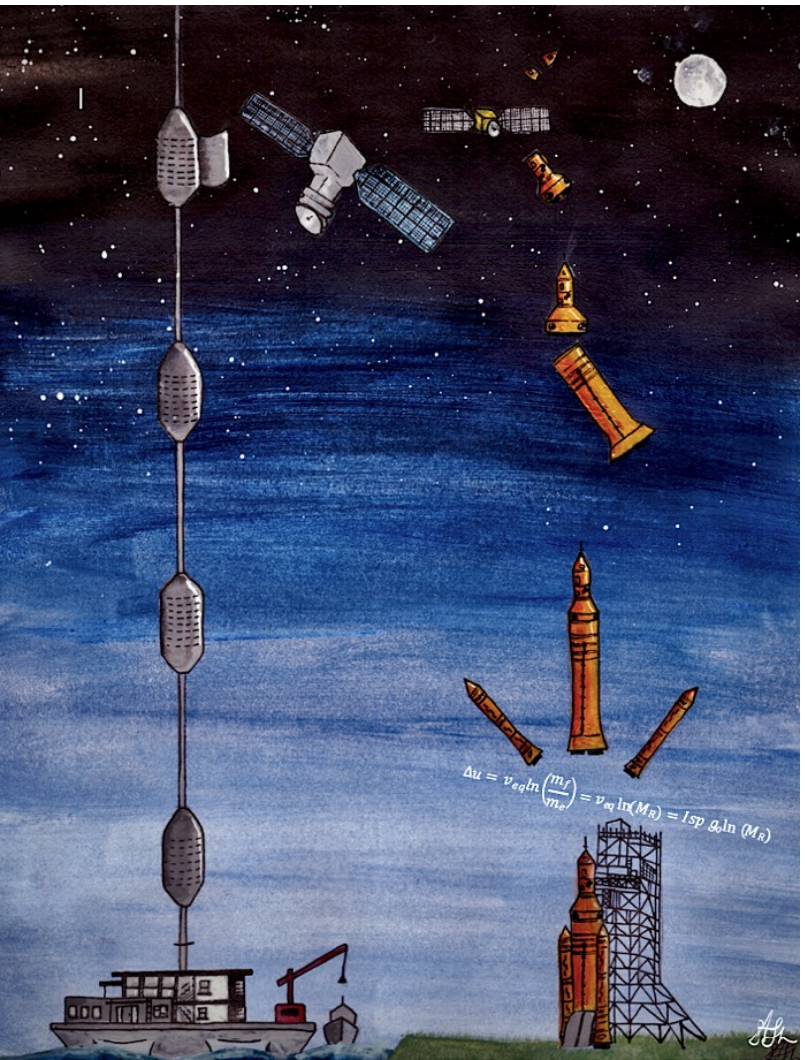
The Space Elevator is ready to Start Engineering Validation!



1. The ISEC team has been assessing the technology feasibility situation since 2008.
2. Recently the team has begun an open dialog with members of industry, academia, and others who could be the deliverers of ISEC solutions.
3. Industry (especially) will show how the needed technologies are being matured and when they could be dependably available.
4. These readiness assessments were the Phase One exit criteria.

Strategy - Dual Space Access Architecture

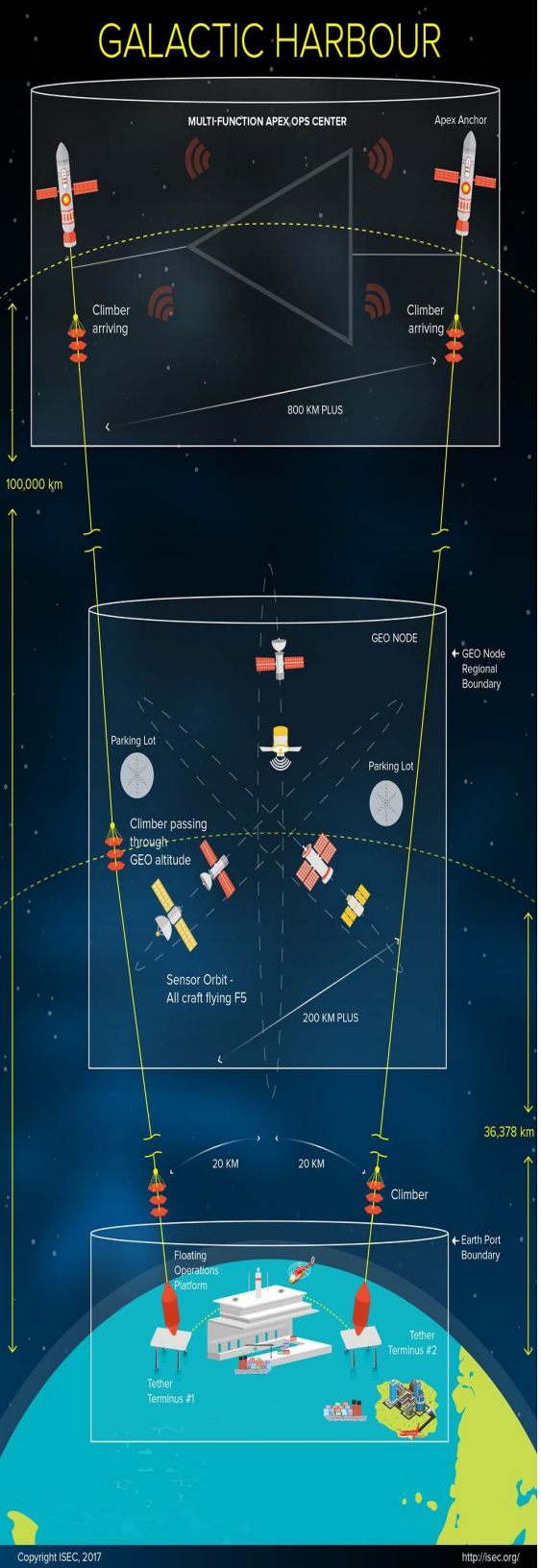
Rockets to Open up the Moon and Mars with Space Elevators to supply and grow the colonies.



Rocket Strengths: (1) Operational today with future growth, 2) rockets reach multiple orbits, and 3) rapid movement is achievable through the radiation belts.

Space Elevator Strengths: As permanent infrastructures they lead to daily, routine, environmentally friendly, and inexpensive departures towards mission destinations

Combination of delivery approaches: Will greatly enhance the missions of the future. When the customer demands for huge masses matures to support critical missions the value of Space Elevators will become obvious.



Basic Message

"Earth Space Elevators Take massive freight to orbit virtually free on the Green Road to Space"

Supporting Messages:

- *We are ready to initiate a Space Elevator Developmental Program.*
- *Our strategy is to propose a Dual Space Access Architecture.*
- *Our visions match yours! We are building the Green Road to Space in response to your vision.*
- *We escape the conundrum of expecting only 2% of mass to reach our destination.*
- *The promise of Space Elevators is so remarkable, we can not wait.*

Why Space Elevators? Because we Must!

- Fulfills the Dreams of Many
- Raises Massive Cargo using Solar Energy
  - Green Road to Space
  - Permanent Infrastructure for GEO & Beyond
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Appendix

A dual space-access architecture

Likely and possible for rockets to deploy the first SPS systems

- Incredibly useful earth-to-orbit systems for deploying new space technologies, opening up new activities
- Will remain the go-to technology for moving humans through the Van Allen radiation belt

Space elevators are needed for high-throughput, massive hardware deployment.

- Consistent, continuous movement of freight to GEO and beyond

Enable space technology deployment at scale for high impact

Rockets and Space Elevators
are complementary technologies
for enabling humanity's expansion into space.

Space Solar Power Cost and Years to Deliver

- Demand at GEO = 5,000,000 metric tons*
  - Number of Atlas launches = (10 tonnes x20/yr) ➡ 25,000 years
  - SpaceX Starship = (20 tonnes x500/yr) ➡ 500 years
  - Cost to GEO ($1,000 /kg) = $5,000,000,000,000
- One conclusion from Dr. Mankins' book: "It is crucial that the systems used for space transportation must be transformed in order for space solar power to become economically viable."

Table 3.2, Reference Destination - Mars

Reference Mission	***Metric Tons to Destination***	***Comment***
Space Solar Power	5,000,000	Power to 12% of Earth's population in an environmentally friendly manner.

*J. Mankins, personal conversation with P. Swan, at IAC, Washington.D.C. Oct 2019.

Operating Safely in Debris Environment

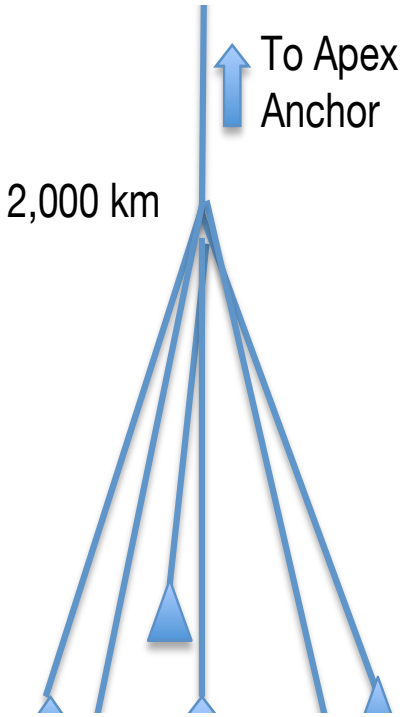
Two Reports and seven pg summary in “Start Now” work book.

- 2010 "Space Elevator Survivability, Space Debris Mitigation."
- 2020 "Today's Space Elevator Assured Survivability Approach for Space Debris.”

"Space debris mitigation is an engineering and management problem with definable quantities such as density of debris and lengths/widths of targets." Space Debris is NOT a show stopper!

Three parallel Activities.

- Passive – multi-leg, tether design,
- Active – move tether, protection, repair climber
- Collaboration – knowledge sharing, active involvement in tracking, coordinate with owners,



ISEC Studies

2021	Design Considerations for the Space Elevator Climber-Tether Interface - in progress
2021	Space Elevators are the Green Road to Space
2020	Space Elevators are the Transportation Story of the 21st Century
2020	Today's Space Elevator Assured Survivability Approach for Space Debris
2019	Today's Space Elevator, Status as of Fall 2019
2018	Design Considerations for a Multi-Stage Space Elevator
2017	Design Considerations for a Software Space Elevator Simulator
2016	Design Considerations for Space Elevator Apex Anchor and GEO Node
2015	Design Considerations for a Space Elevator Earth Port
2014	Space Elevator Architectures and Roadmaps
2013	Design Considerations for a Space Elevator Tether Climber
2012	Space Elevator Concept of Operations
2010	Space Elevator Survivability, Space Debris Mitigation

Completed studies on www.isec.org in pdf format are free

	Other Study Reports
2019	The Road to the Space Elevator Era - IAA IAA = International Academy of Astronautics (https://iaaspace.org)
2014	Space Elevators: An Assessment of the Technological Feasibility and the Way Forward - IAA
2014	The Space Elevator Construction Concept – Obayashi Corporation (https://www.obayashi.co.jp/en/news/detail/the_space_elevator_construction_concept.html)