Dual Space Access: An Evolutionary Step Towards Humankind's Movement Off-Planet

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IAC PARIS 2022

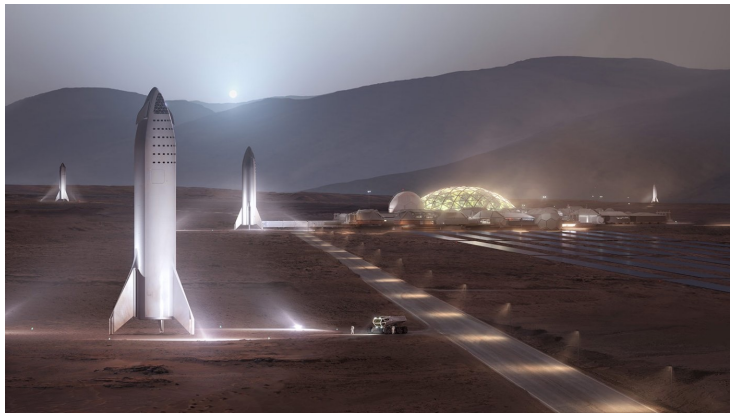
Dual Space Access Architecture

- *Dreamers*
- Space Elevator Vision
- Dual Space Access Future
  - Strengths
  - Weaknesses
- The Way Forward
- Summary

Living and working in thriving communities beyond Earth – NSS

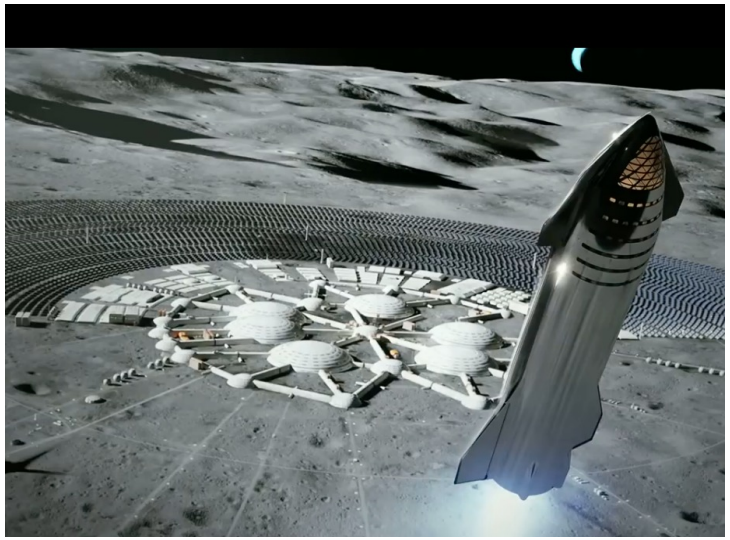
Dream Big!

But How much mass to Orbit?



Images from SpaceX website

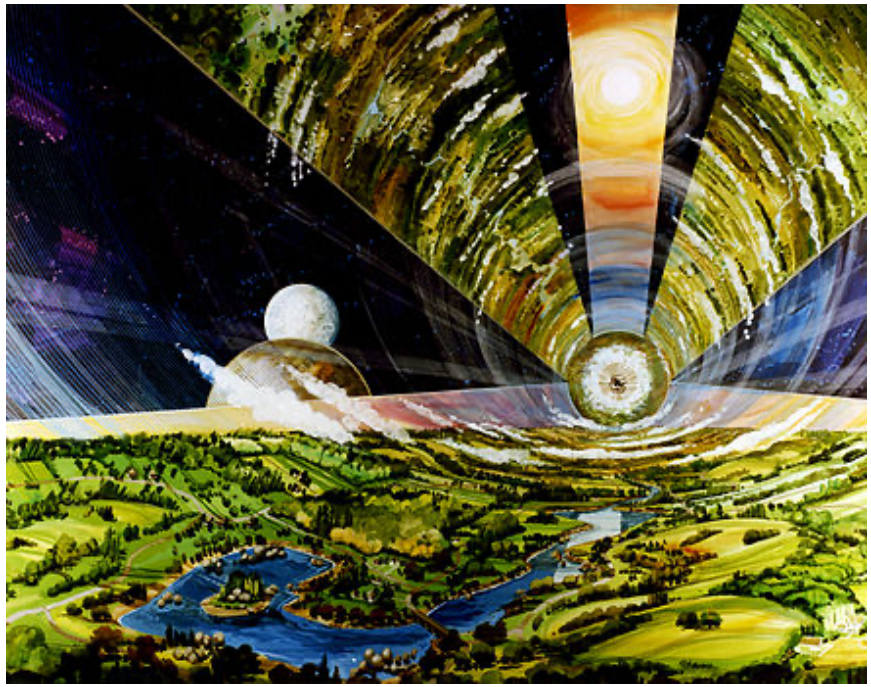
1,000,000 tonnes to Mars surface



Images by NASA and Rick Guidice

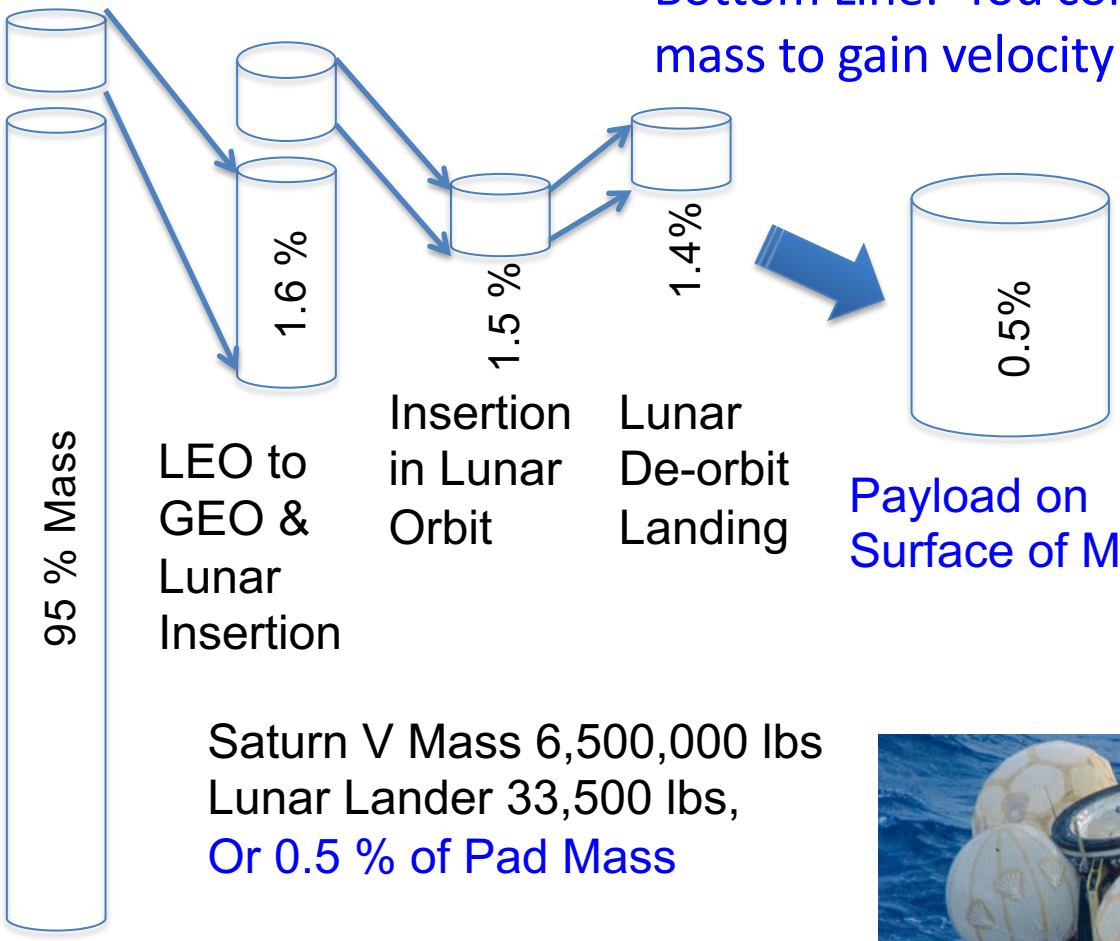
Images from SpaceX 500,000 tonnes to Lunar surface (Swan estimate)

Image from Blue Origin website



Rocket Equation

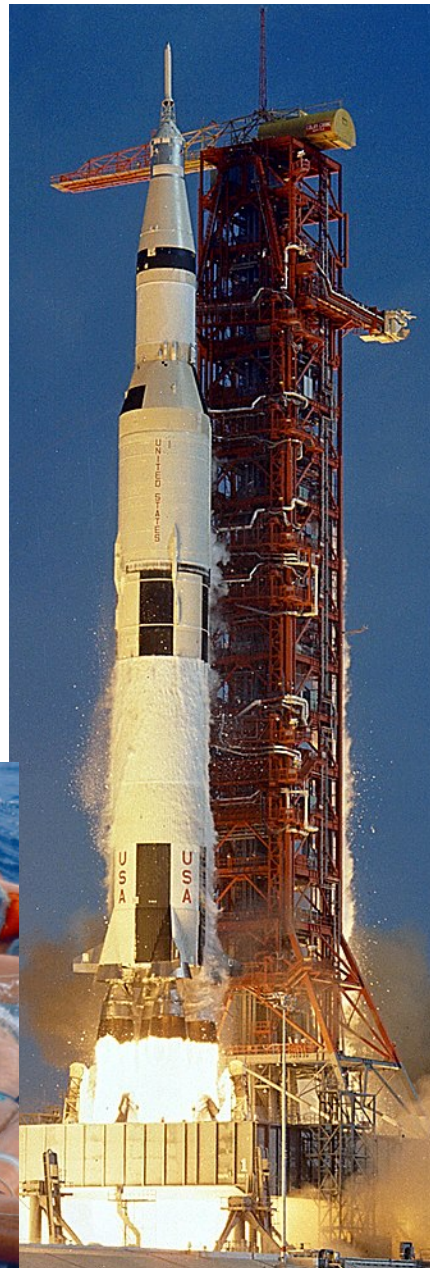
Bottom Line: You consume your pad mass to gain velocity



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

Pad Mass At Liftoff

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



Comparison to Rockets - data varies greatly, only representative

Table 1: Launch Vehicle Delivery Percentages to GEO

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average		4% of Pad mass	1.5% of pad Mass	

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Number of Rocket Launches per year
= 91 average
Over 130 in 2021

Reference Missions:

- Sun-Eath L-1 SunShade – 20,000,000 tonnes well beyond GEO
- 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

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ISEC

7.76 km/sec

Apex Anchor

Tether

Geostationary Node

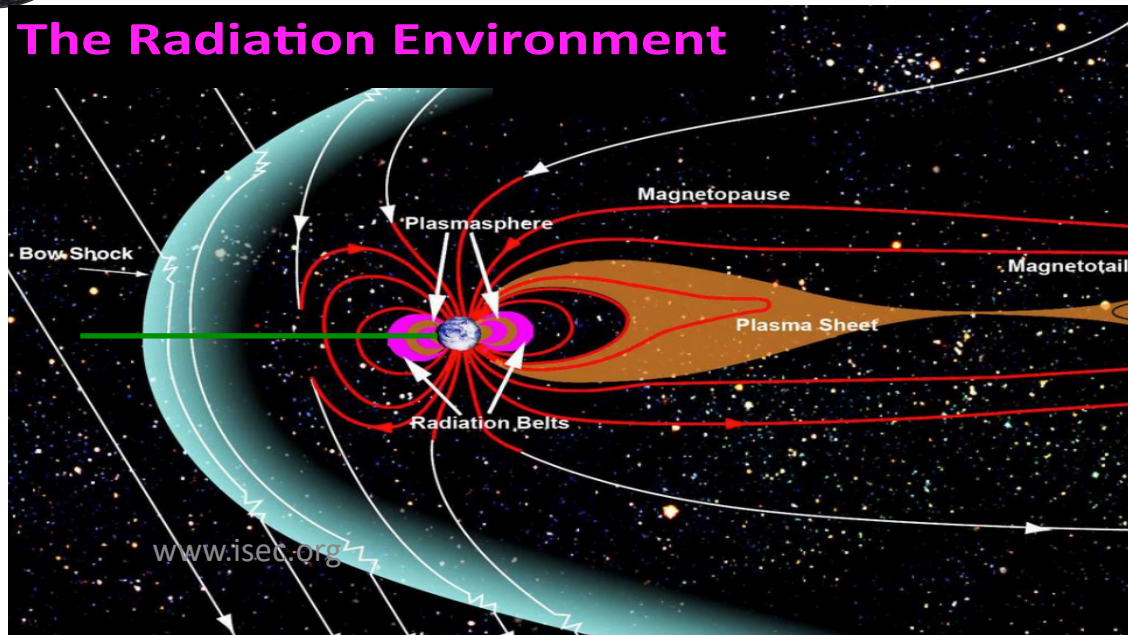
Climber

Marine Node

Diameter of earth 12,742 km

Tether length 100,000 km

The Space Elevator



Space Elevator Vision 2038 Timeline

New 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. This is accomplished safely, routinely, inexpensively, daily, and they are environmentally neutral.*

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.

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

Transformational Characteristics

The transformation of space access will be similar to moving from small boats crossing a large river to a permanent infrastructure called a bridge moving traffic daily, routinely, safely, inexpensively, and with little environmental impact. Permanent transportation infrastructures called space elevators will enable missions by leveraging their strengths:

- Daily, routinely, safely, inexpensively
- Transforming the economics towards an infrastructure with access to more valuable, lucrative, stable and reliable investments.
- Massive movement (30,000 tonnes/yr vs. approx.. rockets' 26,000 tonnes over 65 years)
- Green Road to Space ensures environmentally neutral operations
- High velocity (starting at 7.76 km/sec at 100,000 altitude enables rapid transits)
- Assembly at the Top of the Gravity Well

Annual payload (tonnes/yr)

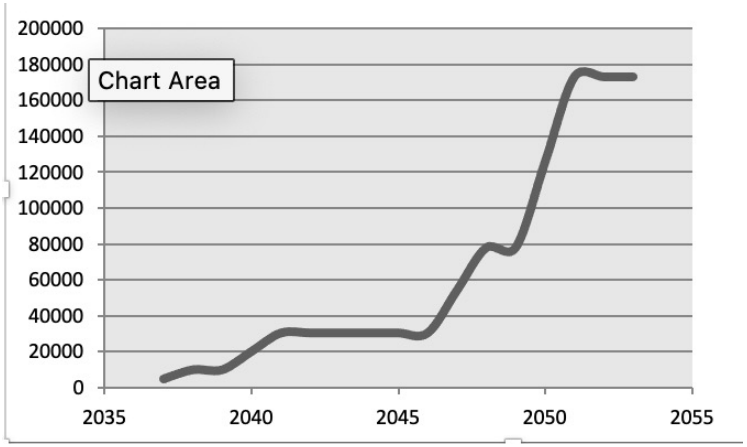
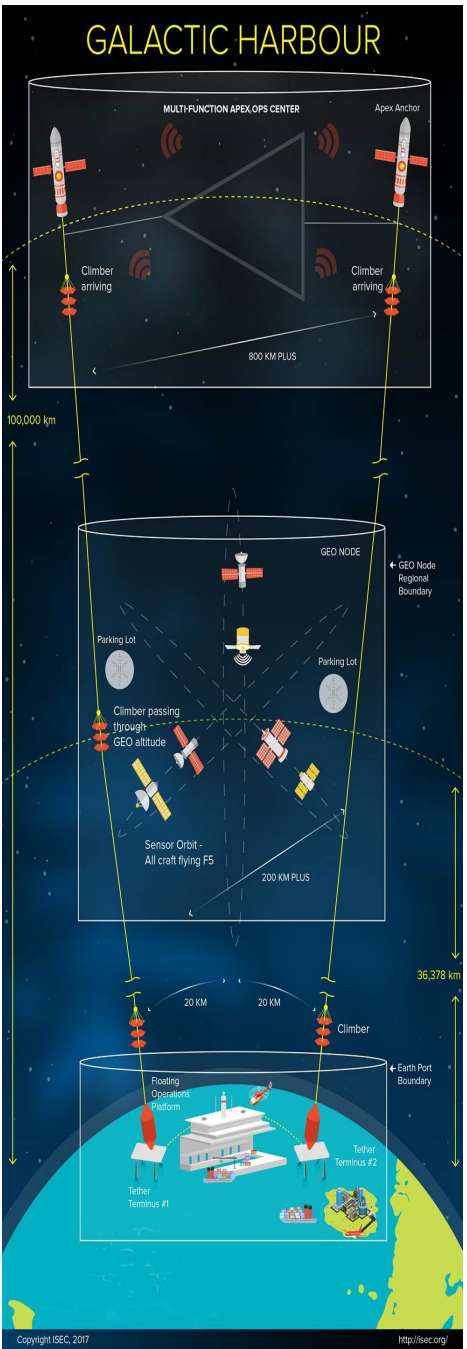
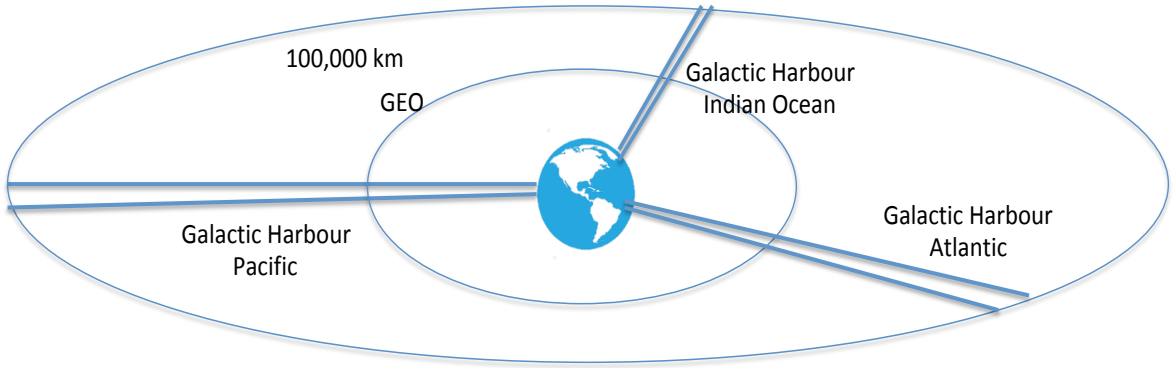


Figure 88. Massive Cargo Movement by Space Elevators (Swan "Dual Space Access Strategy Minimizes the Rocket Equation," Space Renaissance International 3rd World Congress 2021 – Congress Theses, Final Resolution and Papers. Pg 254-255.)

SETS Strength Four: *This Green Road to Space ensures environmentally neutral operations*



A Green Road to Space



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

Space Elevators Beat the Rocket Equation
We Enable Dreams

*(30,000 tonnes/yr vs. approx.. rockets' 26,000 tonnes over 65 years)

SETS Strength Three: *Massive movement (30,000 tonnes/yr vs. approximately. 26,000 tonnes over 65 years by rockets)*

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

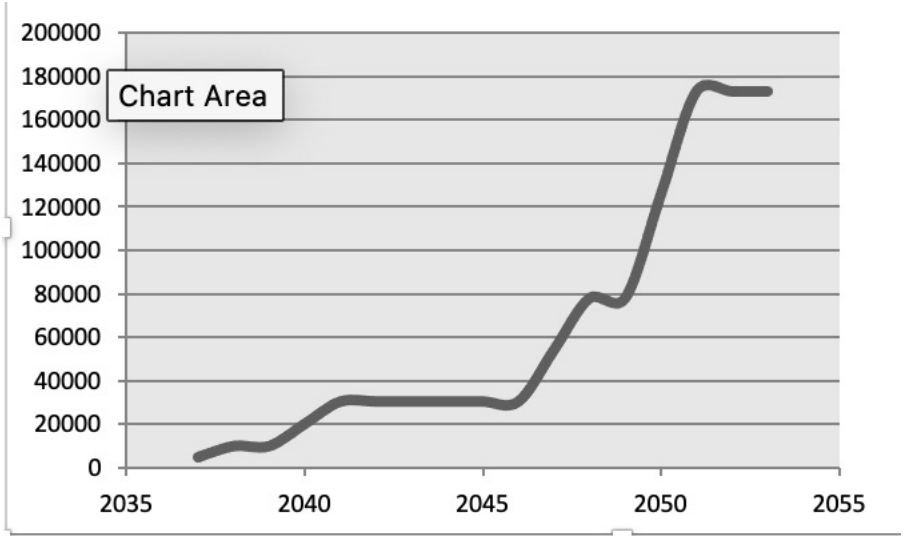
Note: Leo is 4% of launch pad mass
GEO, Interplanetary, Lunar 2% of pad
*Shuttle launch vehicle reached orbit as an operational satellite

Historic Movement
(1957 – 2020)

22,216 tonnes between 1957 and 2020.

Space Elevator expected
movement of mass
Initial Operations Capability (30,000 tonnes/yr)
Full Operations Capability (170,000 tonnes/yr)

Annual payload (tonnes/yr)



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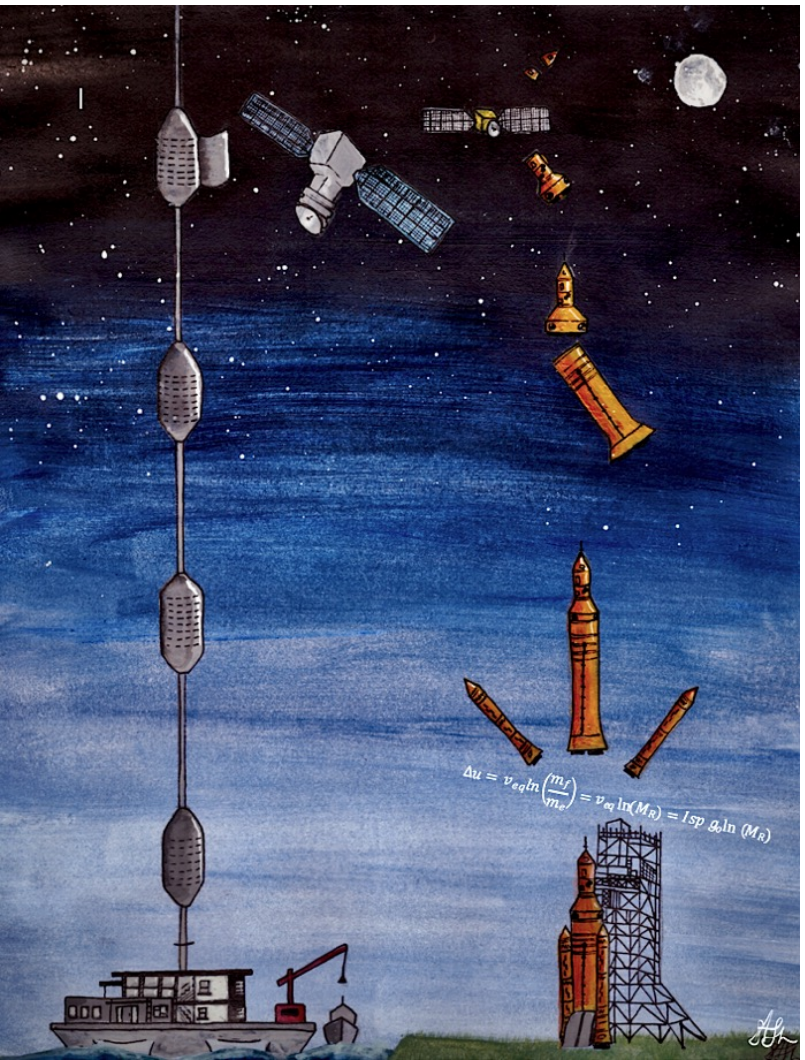
Dual Space Access Architecture

Rockets to Open up the Moon and Mars with Space Elevators to supply and grow the colonies. In addition, Rockets would delivery prototypes and initial operational Space Solar Power Satellites, while Space Elevators would fill out the constellations with the heavy lifting.

Image by Amelia Stanton



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.

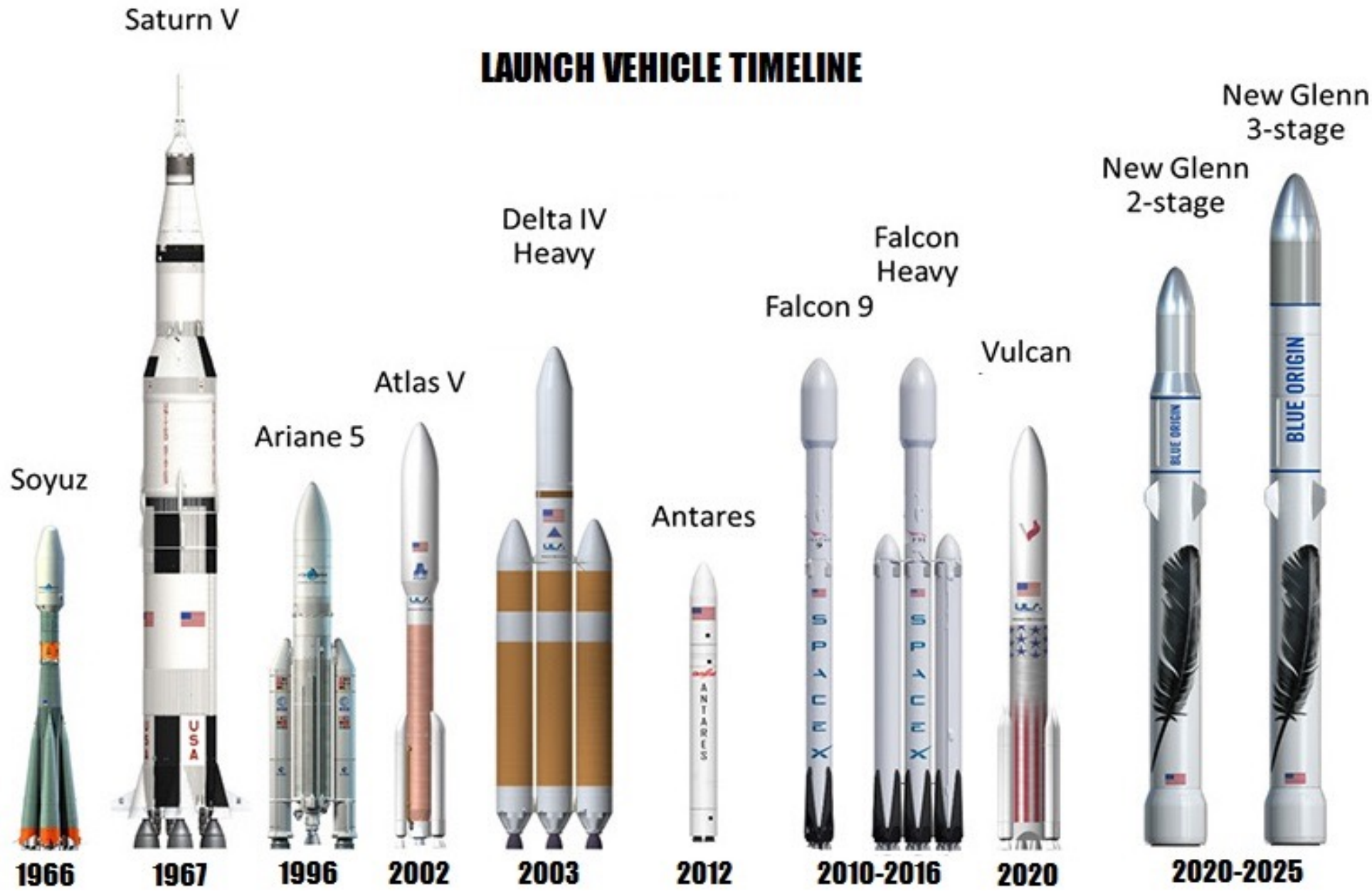
Rocket Strengths: (1) Operational today with future growth, (2) rockets reach multiple orbits, and (3) rapid movement through the radiation belts

Collaboration and Cooperation

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

Minimizing the Rocket Equation Limitations


JACK BEYER
NASA
SPACEFLIGHT.COM


LAUNCH VEHICLE TIMELINE
Soyuz
1966
Saturn V
1967
Ariane 5
1996
Atlas V
2002
Delta IV Heavy
2003
Antares
2012
Falcon 9
Falcon Heavy
2010-2016
Vulcan
2020
New Glenn 2-stage
New Glenn 3-stage
2020-2025

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= 91 average
Over 130 last year

Reference Missions

Geosynchronous Space Based
Solar Power; 5,000,000 Metric tonnes

Mars Colony; Musk's Estimate;
1,000,000 tonnes

Total Mass to Orbit 1957-2020
22,216 tonnes

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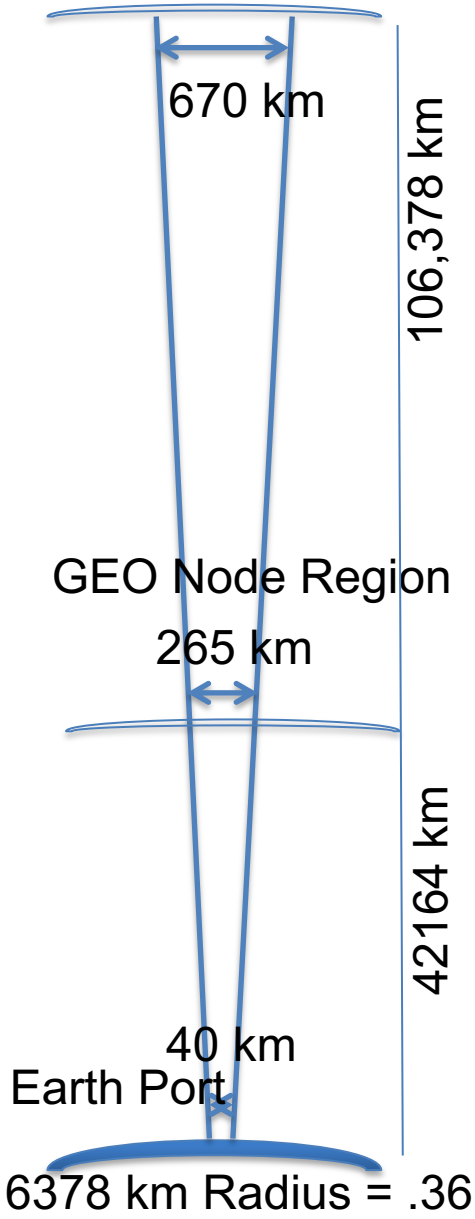
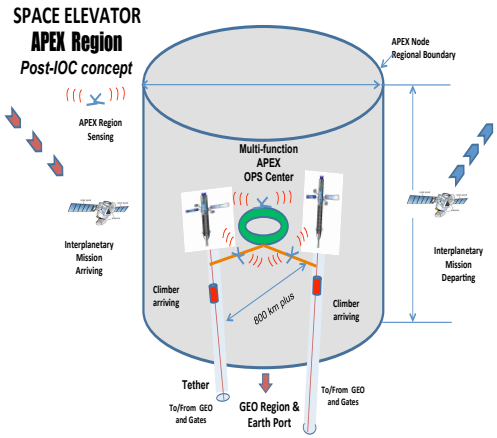
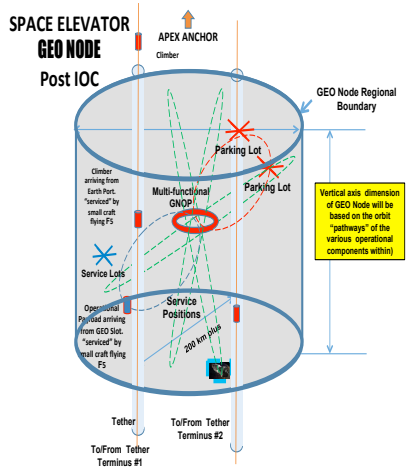
GEO, Interplanetary, Lunar 2% of pad

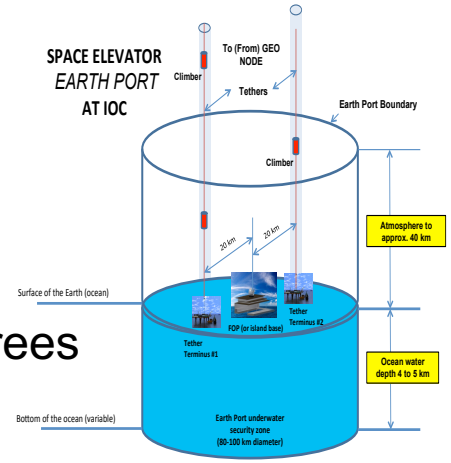
*note: Shuttle was a launch vehicle itself, but gained orbit, so mass to orbit

**note: estimated mass at 1,000 kg each









- Galactic Harbour includes two Space Elevators radially extending from Ocean surface to Apex Anchor for a permanent space access infrastructure.
- One reusable tether climber lift-off per day
- Three Regions, Earth Port – GEO – Apex Anchor, where commercial ventures will grow

Characteristics of Permanent Transportation Infrastructure

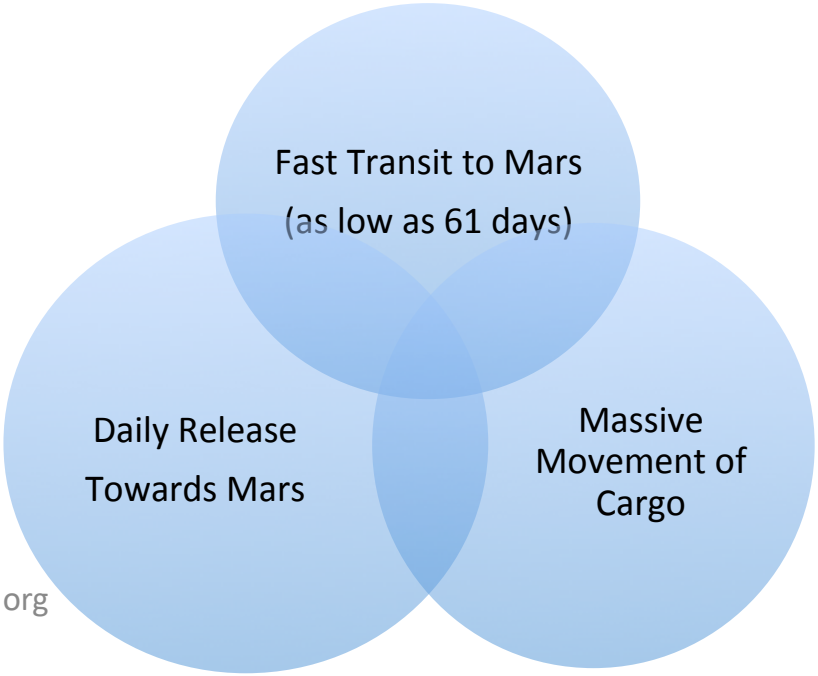
- Revolutionarily inexpensive to GEO [$100/kg to GEO]
- Commercial development similar to bridge building
- Routine [daily launches]
- Safe [no chemical explosions from propulsion]
- Permanent infrastructure 24/7/365/50 yrs. [bridge similarities]
- Massive loads with daily launches per elevator (30,000 tonnes per year to GEO & beyond (early operations))
- 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

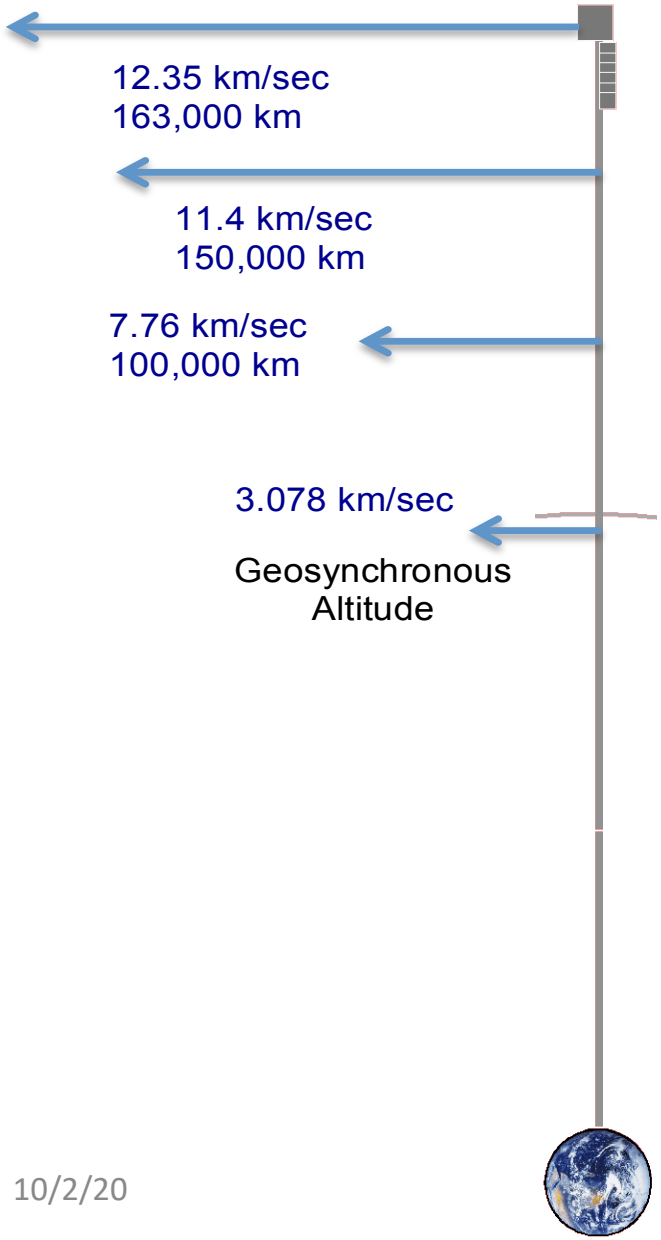
Enable Interplanetary Mission Support

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

- Rapid Transit to Mars (61 days best with many between 80 to 100 days)
- Release every day towards Mars (no waiting for 26 month window)
- Massive tonnage of mission support equipment (170,000 tonnes per year with a mature system)

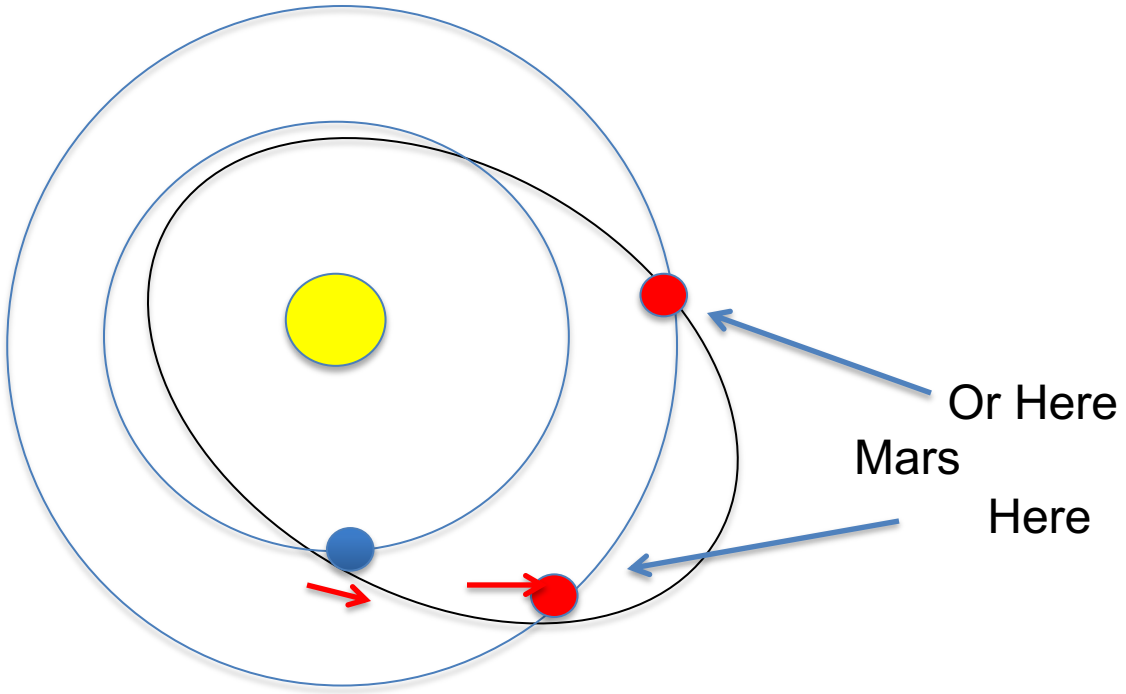


SETS Strength Five: *High velocity (starting at 7.76 km/sec at 100,000 km altitude) enables rapid transits*



- This new vision of Galactic Harbour architectures will change the "thinking" for off-planet migration – How fast can we go?
- At 100,000 km altitude, there is no significant gravity pull to limit departures
- At 100,000 km altitude, there is tremendous velocity (7.76 km/sec) enabling beyond Mars
- With longer Space Elevators, the whole solar system opens up and even escape from the sun is possible (without thrusting from rocket fuel).

Case One: Fastest Approach

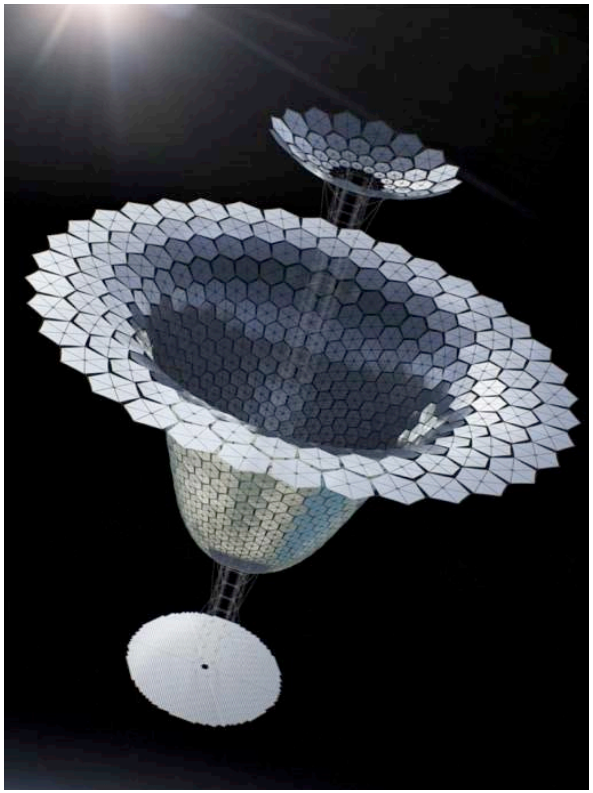


Concept: Our spacecraft enters the ellipse, “not at perigee,” but on the side of the ellipse centered as one foci at the Sun and outer portion matching Earth and Mars locations.

An Example of Near Term Needs Requiring Assembly at GEO

- "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



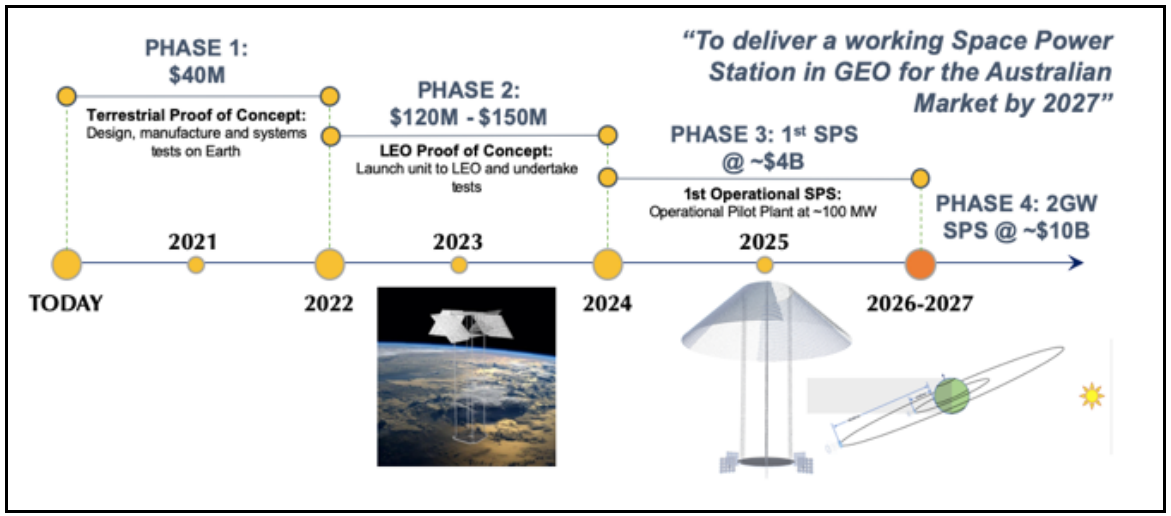
Each Alpha Mark IIIA is 9,800 tonnes (to GEO) - For output of 2 Gwatt continuous power

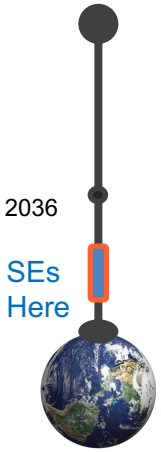
Note: several other designs are lighter, but produce less energy.

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

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ISEC has Initiated a Global Study of DSAA

- The team has been formed and the initial discussions across the globe have been started to complete an 18-month technical study addressing the strengths of this new strategy.
- The study has been authorized by ISEC to illustrate the tremendous strengths of the Space Elevator and compare them to advanced rockets.
- This relationship will lead to a joint architecture leveraging the strengths of both approaches for moving people and cargo.
- It is envisioned that the Space Solar Power mission to save the Earth's environment and the Missions to Mars and the Moon are of incredible size and scope carrying the dreams/visions of many. All of these immense endeavors will require huge amounts of logistical support. This will require a large number of rocket launches with a possible negative impact on the Earth's environment.
- The ISEC has always assumed that operational Space Elevators would have little or no environmental impact and that a number of environmental problems could possibly be solved, if a cheap reliable access to GEO existed using electricity to raise the climbers.
- This study will investigate the strengths of both space access architectures and compare / contrast the strengths and weaknesses of both. In addition, multiple case studies will be incorporated into the report to enable a Dual Space Access Strategy to mature and emerge.

Outline of Report

- Chapter 1: Introduction and Summary of the findings
- Chapter 2: Dreams of Many lead to Visions (each with a mass to GEO and Beyond identified – Elon Musk, Jeff Bezos, National Space Society (L-5 Colony), Lunar Village, Space Solar Power)
- Chapter 3: Space Elevator Strengths / Shortfalls -- Massive Movement, Green Road to Space, Routine and Fast to Mars and beyond, Routine daily, cost effective safe, Not here today, Slow to GEO and Beyond (once released fast)
- Chapter 4: Rocket Strengths / Shortfalls -- Operational today, Rapid transit to LEO/GEO and the Moon, Fast thru radiation, Delivery statistics of cargo (2% of pad mass to GEO)
- Chapter 5: Case Study: Space Solar Power
- Chapter 6: Case Study: Access for Mars
- Chapter 7: Case Study: Lunar Village
- Chapter 8: Case Study: L-5 Colony
- Chapter 9: Case study: Sun shades to cool Earth
- Chapter 10: Case study: Planetary Defense
- Chapter 11: Case study: Planetary Sciences
- Chapter 12: Case Study: Missions accomplished only by SEs
- Chapter 13: Conclusions / Recommendations

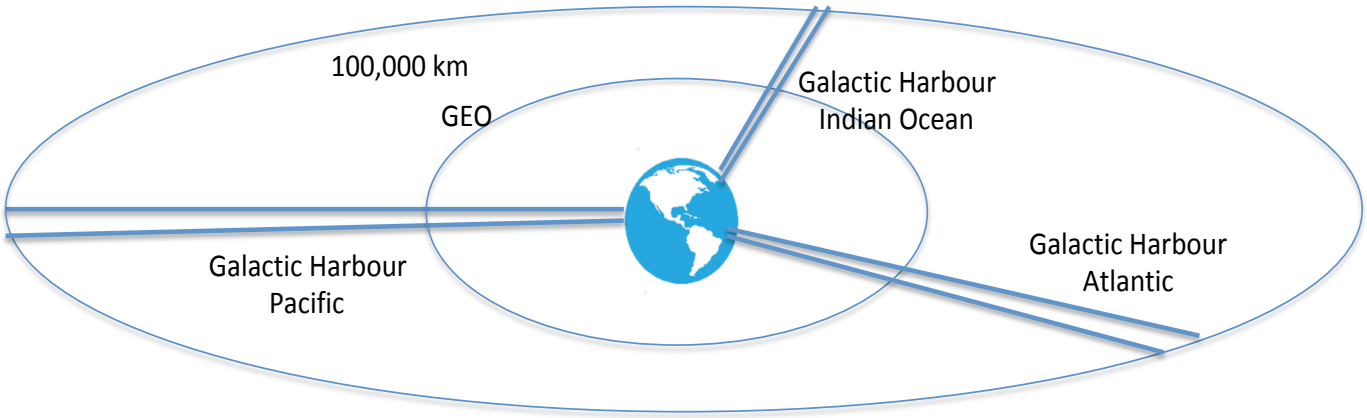
Recognize the Conundrum of Rockets

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

Vision of Galactic Harbours – A Green Road to Space



Permanent Transportation Infrastructure lifting Massive tonnage by electricity to GEO and beyond, daily, routinely, inexpensively, and safely

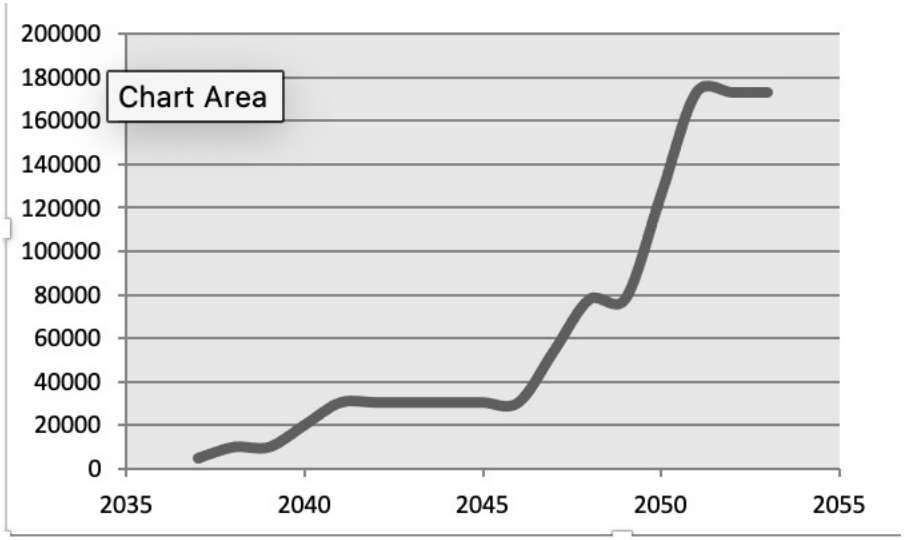
Three Galactic Harbours

– 7 climbers a week/elevator

– 14 tonnes payload each, x2 x3 or 30,000 tonnes/yr

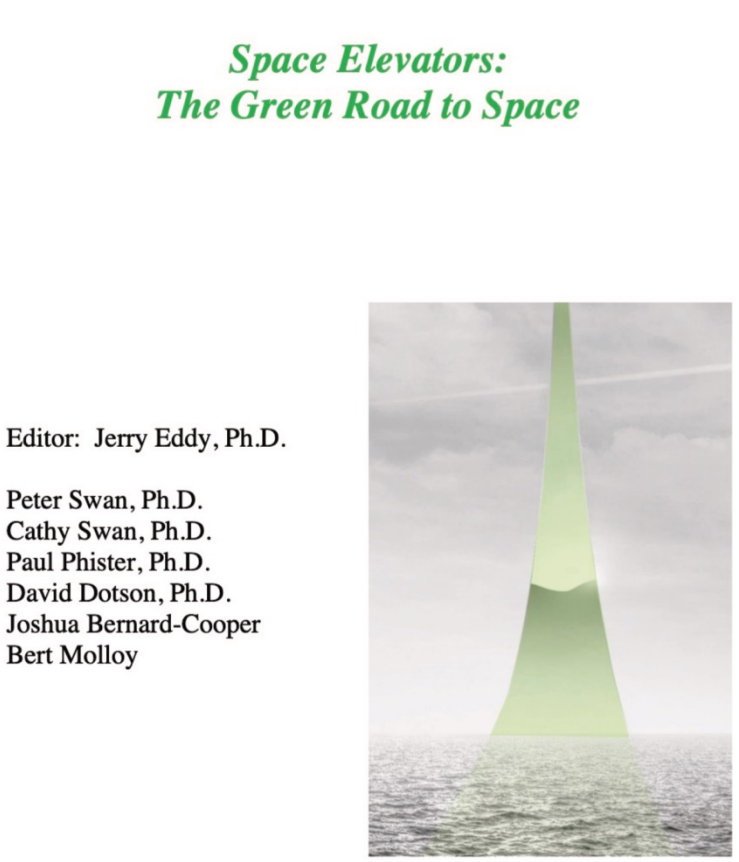
– expanding to 80 tonnes payload each, or 170,000 tonnes/yr

Annual payload (tonnes/yr)



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



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Encourage Reference Missions as Achievable:

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- 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

Modern Day Space Elevator
Transforming Space Access

What is a Modern Day Space Elevator?

The term “A Modern Day Space Elevator” has evolved from a dream to a scientific engineering reality. The four major thrusts for the present Modern Day Space Elevator are:

- Space Elevators are ready to enter Engineering Development (Phase Two of development)
- Space Elevators are the Green Road to Space
- Space Elevators can join advanced rockets inside a Dual Space Access Architecture
- Space Elevator’s major strength as a permanent transportation infrastructure is movement of massive cargo to GEO and beyond enabling new enterprises along the way.

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