Transformational Release of Scientific Payloads From the Apex Anchor Any Size, Every Day, Anywhere

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Note: image from Heinlein Prize Trust and Excalibur Exploration – and IAA Study

ISEC

7.76 km/sec

Apex Anchor

Tether

Geostationary Node

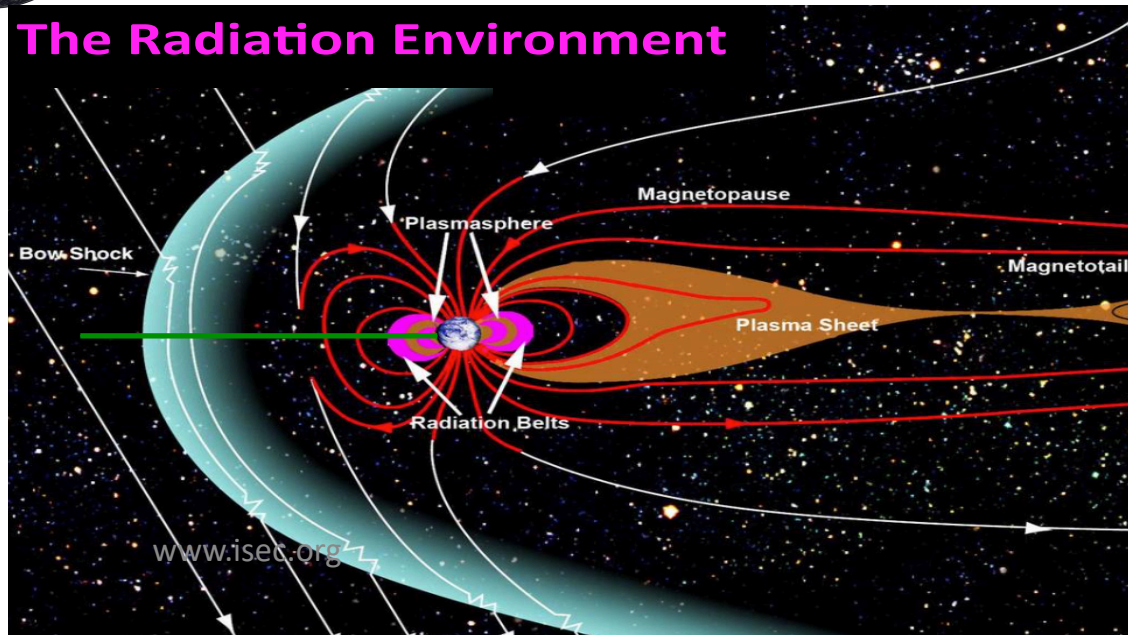
Climber

Marine Node

Diameter of earth 12,742 km

Tether length 100,000 km

The Space Elevator



Agenda

- Introduction
  - Historic Look
- Excitement for our future
  - Decadal Survey
  - Future Rocket Capability – Evolutionary Leap
  - Space Elevator Transformational Characteristics
- Dual Space Access Architecture
  - Advanced Rockets
  - Mars Study
- Assembly at Top of Gravity Well
  - Space Elevator Transportation Infrastructure
  - Apex Anchor Robotic Assembly
  - Range of Velocities
- Conclusions
  - Any Size – Any Mass – Every Day – Any Destination

Multiple Visions

- National Space Society (US) - "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."
- The British Interplanetary Society mission – To promote the exploration and use of space for the benefit of humanity.
- Mr. Bezos - "millions of people living and working in space" or maybe: "I am going to build the road to space."
- Mr. Musk – "Making Humanity Multiplanetary"
- NASA - With the Artemis program, NASA will land the first woman and next man on the Moon by 2024, using innovative technologies to explore more of the lunar surface than ever before. Artemis Accords Signed by:Australia, Canada, Italy, Japan, Luxembourg, United Arab Emirates, United Kingdom, and United States of America. (2020)
- ESA - "This MoU marks a critical point in Europe's trajectory: it confirms we are going forward to the Moon, not just in terms of equipment and technology, but also with our people. Europe will play a central role in the new era of global space exploration along with NASA and our partners, delivering exemplary, game-changing architectures to explore the Moon and Mars and inspiring generations to come." (Mr. Wormer 28 Oct 2020)

Currently towards to Mars- UAE, China, US

(dated information)

Emirates Mars Mission	19 July 2020[23]	MBRSC United Arab Emirates	Orbiter	En route	Arrives February 2021.	H-IIA
Tianwen-1 orbiter	23 July 2020[24]	CNSA China	Orbiter	En route	Proposed orbit insertion: 11-24 February 2021	Long March 5
Tianwen-1 lander/rover	23 July 2020[24]	CNSA China	Lander/rover	En route	Proposed landing: 23 April 2021	Long March 5
Tianwen-1 deployable camera[25]	23 July 2020[24]	CNSA China	Imager (flyby)	Successful	Photographed the Tianwen-1 spacecraft while en route to Mars. Will flyby mars. Deployed from Tianwen-1	Long March 5
Perseverance rover	30 July 2020[26]	NASA United States	Rover	En route	Proposed landing: 18 February 2021[27]	Atlas V 541
Ingenuity helicopter	30 July 2020[28]	NASA United States	Helicopter	En route	Proposed landing: 18 February 2021[28] To be deployed from the Perseverance rover.	Atlas V 541

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

Transition Meets Expected Capability

- Science projects for next 20 - 30 years evaluated and selected based on “Launch Constrained” mindset of mass, volume and cost – Due to launching on Rockets!
  - Rockets have mass limitations, challenging payload environmental factors during launch and space, weight and power restrictions which drive system cost to design, develop, procure and test
- Designers now, must evaluate trades between one instrument and another to be able to decrease their mass by insignificant margins, a couple of grams potentially, which drives greater design cost
  - Developers driven to design/procure more exotic solutions, to be able to fit Size, Weight and Power requirements which are much more expensive
  - Payload designs also built and tested to make them able to survive a potentially damaging launch environment

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Excitement: 2022 Decadal Survey "Origins, Worlds, and Life" Excitement!

- Identifies highest priority NASA missions for next Decade 2023 – 2033
  - Will help answer the science communities' highest priority questions
- Board evaluated mission's ability to address key questions and feasibility based on required technology maturity level, risk, and cost in order to prioritize them
- Evaluated and prioritized over 50 different projects/missions (not all were selected) - Note: **Very little** consideration for larger capacity transportation (our reading of documents).
- Expand knowledge of our Solar System – Continue to pursue the Mars Sample Return (MSR) and EUROPA Clipper Flagship ($3.5 – 5.5B) missions currently being acquired by the Jet Propulsion Laboratory at Pasadena CA – Two new ones selected:
  - Visit the gas giant planet Uranus to better understand how our solar system formed
  - Saturn's icy ocean moon Enceladus to gain insights into potential life there
  - In addition, three New Frontier missions ($1.65B), five Discovery missions (.8B) and four SIMPLEx ($80M) missions to be executed over the next couple of decades

Many exciting missions supporting science throughout the Solar System for the next 30 years and ambitious manned missions to the Moon and Mars!

Excitement: 2022 Decadal Survey "Origins, Worlds, and Life"

- Additional Missions evaluated and endorsed:
  - Endurance-A mission - a rover to collect samples across the lunar south pole which will then be retrieved by Artemis astronauts
  - Mars Life Explorer for in-situ resource utilization (ISRU) of water to demonstrate and learn about the ability to use the moon's water
  - Double Asteroid Redirection Test (DART) mission is planned to understand how much an impact to the asteroid will move its trajectory. `

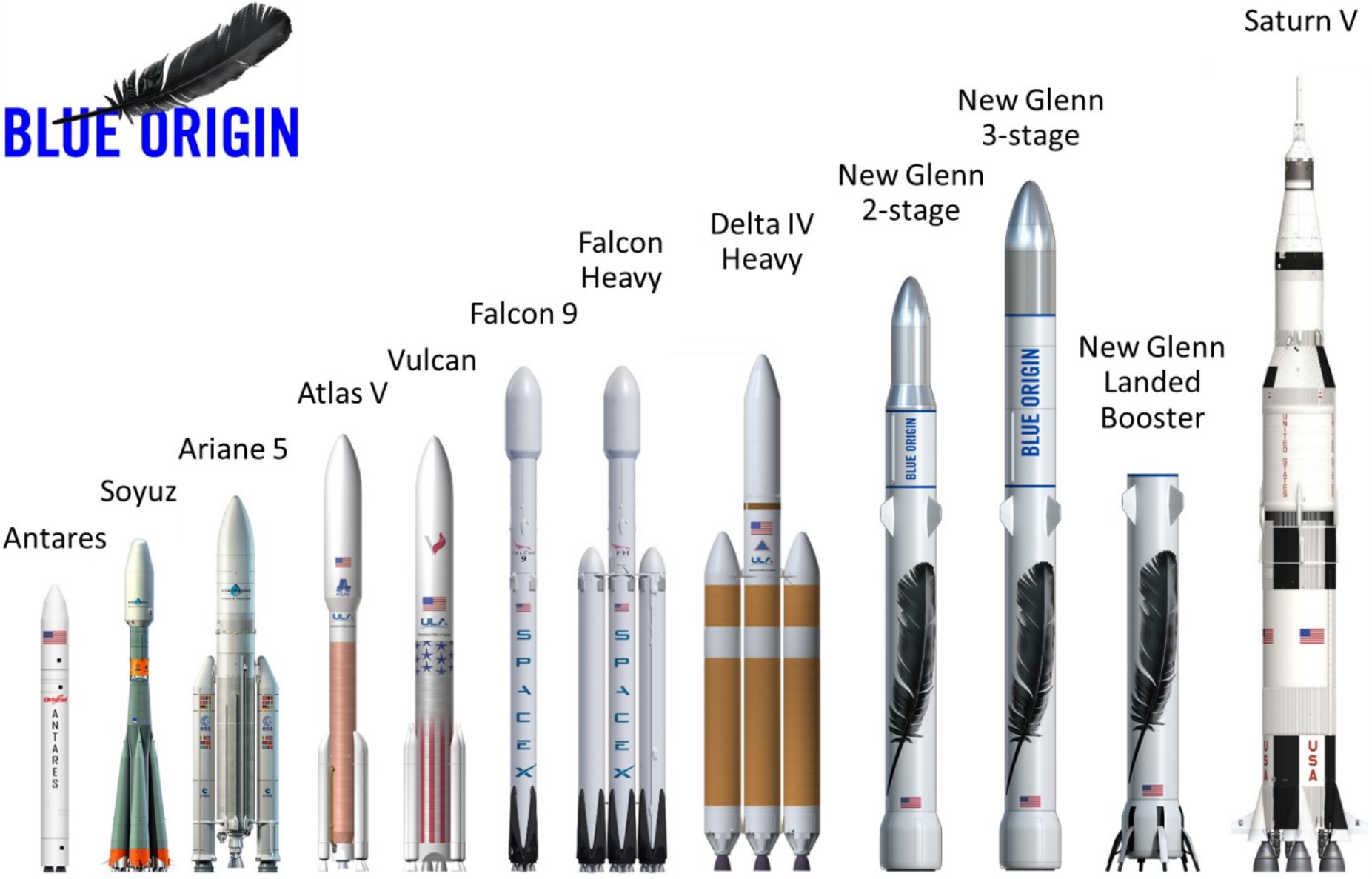
Many exciting missions supporting science throughout the Solar System for the next 30 years and ambitious manned missions to the Moon and Mars!

NASA to Buy Delivery to Surface of the Moon

- Amazon boss Jeff Bezos wants to start delivering packages to the Moon. According to The Washington Post, Bezos – who owns private space travel company Blue Origin – has written an internal report arguing that a good delivery service will be key to establishing a functioning lunar settlement. In the document, Bezos says he hopes to push NASA to develop "incentives to the private sector to demonstrate a commercial lunar cargo delivery service" by 2020, enabling an Earth-to-Moon equivalent of Amazon Prime. The report also includes a description of a new Blue Moon vehicle that would carry as much as 10,000 pounds of cargo, and land on the Moon's sunny South Pole.
- Blue Origin said in a press release, that "both the Blue Moon mission and Moon Race are in line with its goal to land large payloads on the Moon that can access and utilize the resources found there".

New Glenn Comparison

BLUE ORIGIN



NASA Driven Design

Competition

- Government vs Commercial
- Vision driven or funding driven
- Technologies are there, designing for environment is difficult.

Commercial
Driven Design

NASA Image, USA Today,

Starship Fully Reusable

Fig.4. Vehicle overview: Falcon 1, Falcon 9, Falcon Heavy and BFR

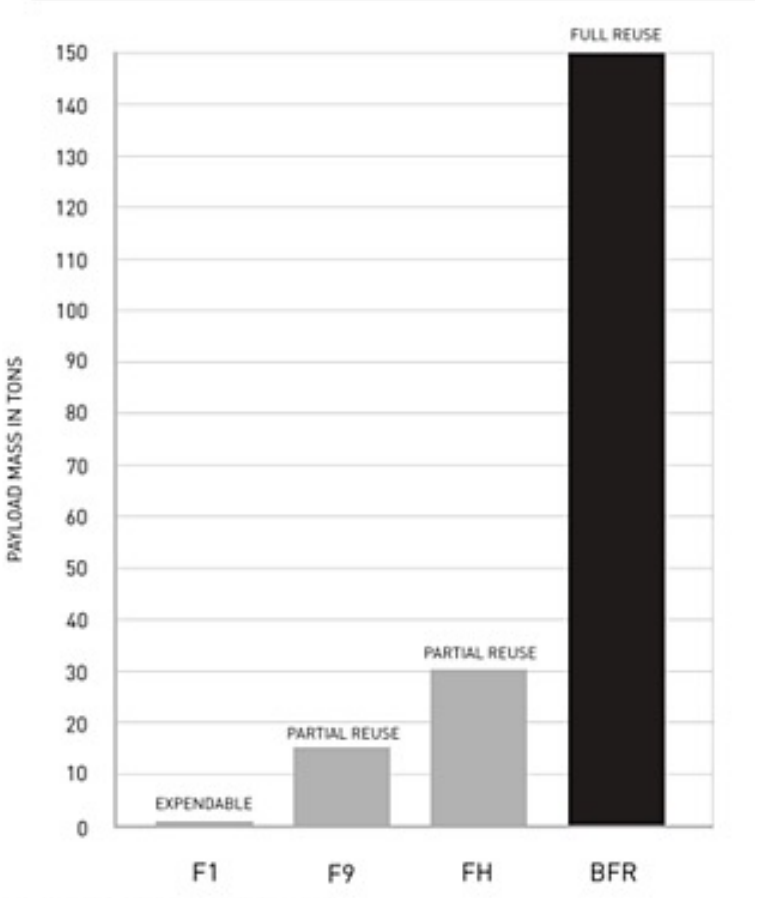
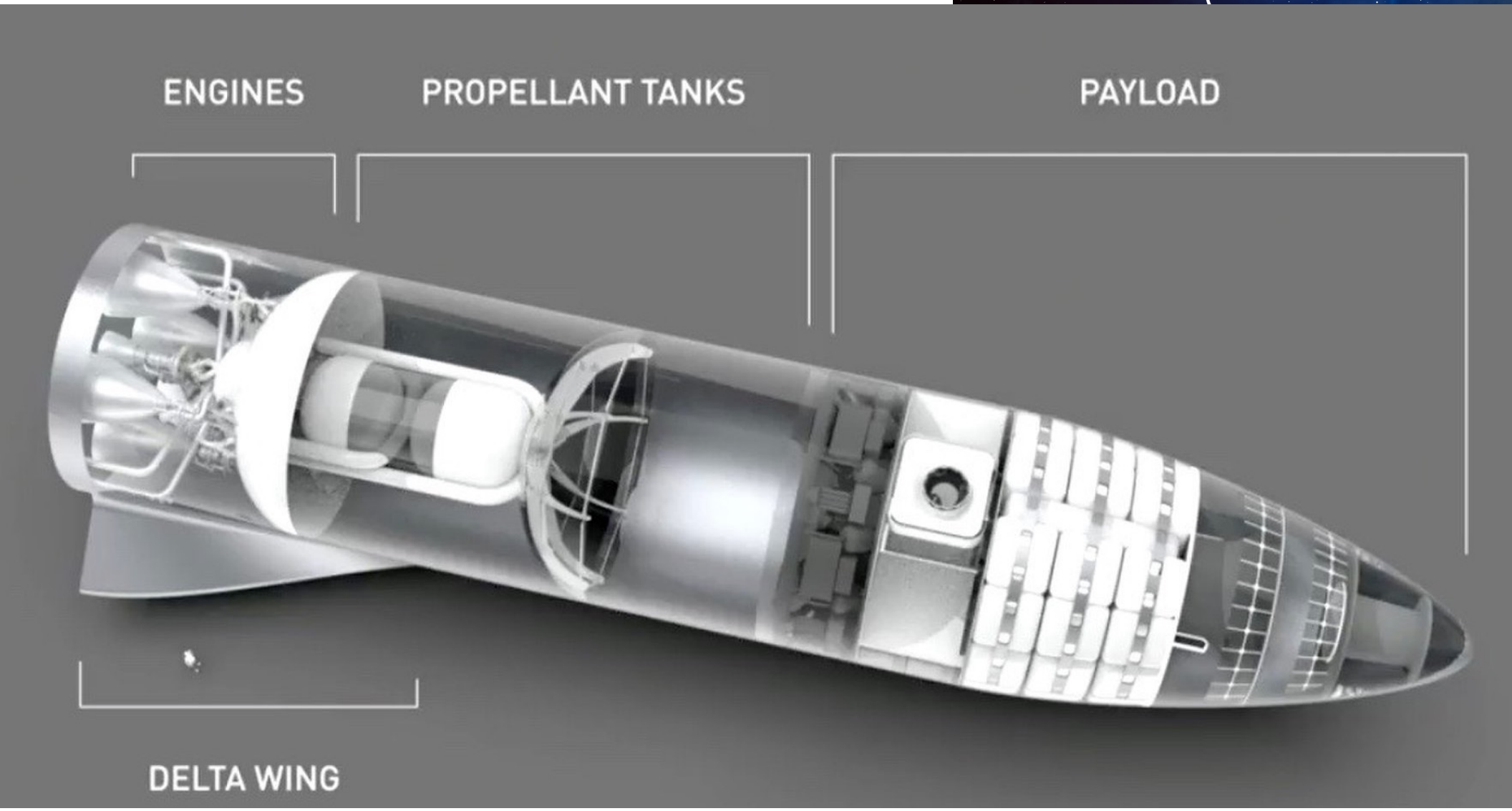


Fig.5. Vehicle payload comparison in tons

100 + people in Starship and
100 + tonnes to LEO



Starship on Moon

- SpaceX's approach is quite different than standard approach – direct to LEO, then refuel, then direct to Lunar surface – then return to land on Earth
- Quite different than the NASA approach to go to LEO, then match orbits with Gateway around Moon, then transfer to lander and then reverse it.
- Of course the Lunar lander program is a commercial one with competition

Revolution in Capacity to Space

- The REVOLUTION is here! Mass and enormous volume can be inexpensively launched into space with corresponding impact on payload size and shape
- The Future is Brilliant!
  - Historically, Scientific Community has had to identify, design, build and launch missions based on launch constrained assumptions:
  - Cost per pound, mass, and volume limitations – leading to size, weight and power (SWAP) constraints
- Artemis and Starship will be the next step in reducing launch limitations and will provide unparalleled access to space to the space faring community
- Cost per launch on Starship should be less expensive for dedicated spacecraft missions
  - Ability to ride share on flights to the Moon and Mars will increase delivery of science payloads along with exploration
  - Refueling Starship in LEO opens enormous possibilities to reach the Moon, Mars and the limit of our solar system (Lets fill up on Mars!)
- *Space Elevator permanent space access infrastructure will deliver 30,000 tonnes to GEO and beyond per year at Initial Operations.*
- *Combined Starship, Artemis and Space Elevator capabilities – out of this world*

When looking at the remarkable future lift capabilities, the science community should dream "bigger" than before

Starship Overcomes Constraints

- Starship's Tremendous Capabilities:
  - 150 tons to LEO – the payload fairing is 9 m (27 ft) in diameter and 18 m (54 ft) high - largest operational payload volume of any current or in development Launch Vehicle
  - Starship cost based on re-usability, flying frequently with cheap maintenance between flights
  - Initial cost of building Starships spread over many missions making initial investment almost negligible
- Positively affects launch constraints - mass and usable launch volume greatly increased enabling more massive payloads and greater variety of shapes
- Greater mass and volume enable payload developers to spend less time and money to develop extreme SWAP technologies and solutions
- Boon to the scientific community allows focus on conducting best science vs making payloads fit launch "packaging" constraints

Reference Missions:

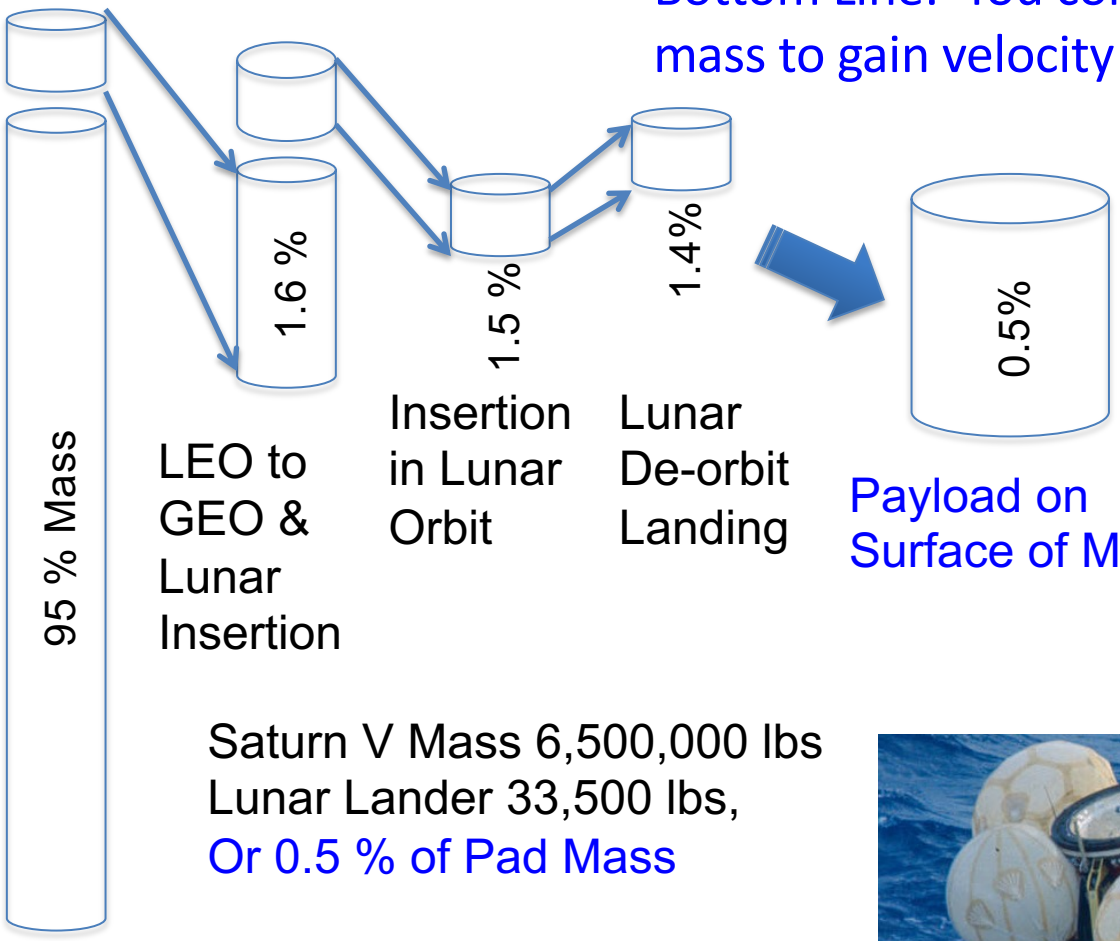
- Sun-Eath L-1 SunShade – 20,000,000 tonnes well beyond GEO

- 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

Rocket Equation

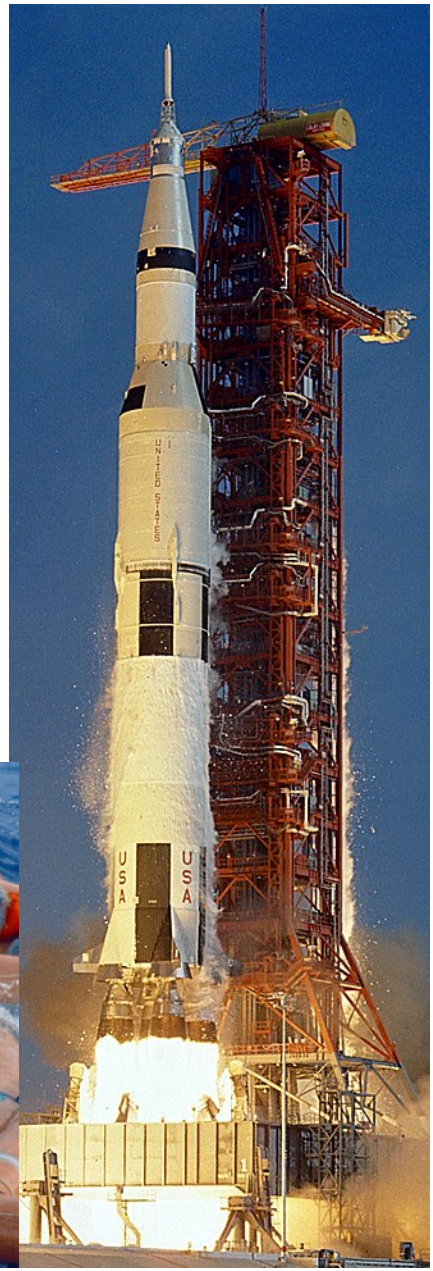
Bottom Line: You consume your pad mass to gain velocity



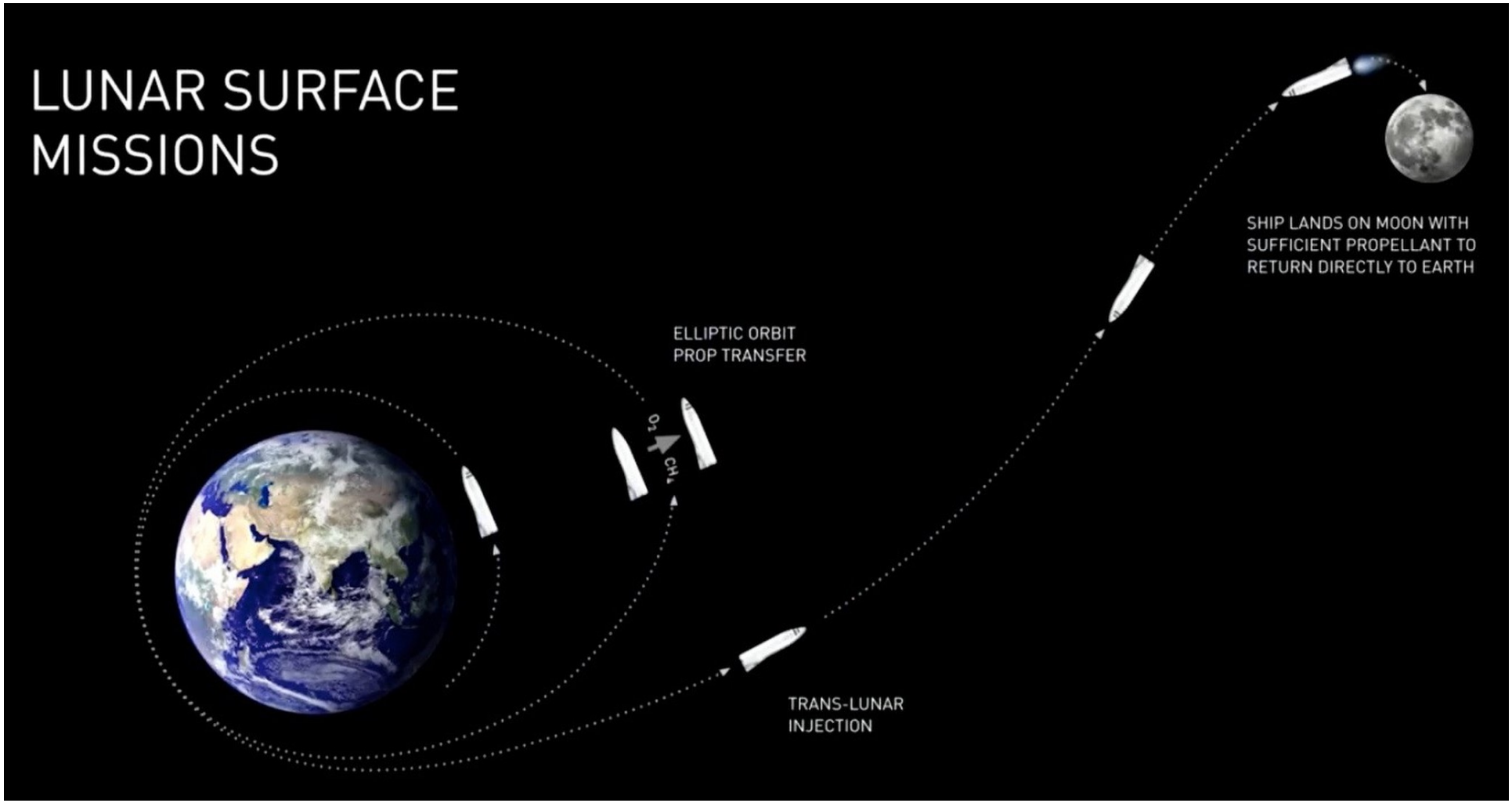
Saturn V Mass 6,500,000 lbs
Lunar Lander 33,500 lbs,
Or 0.5 % of Pad Mass

Pad Mass At Liftoff

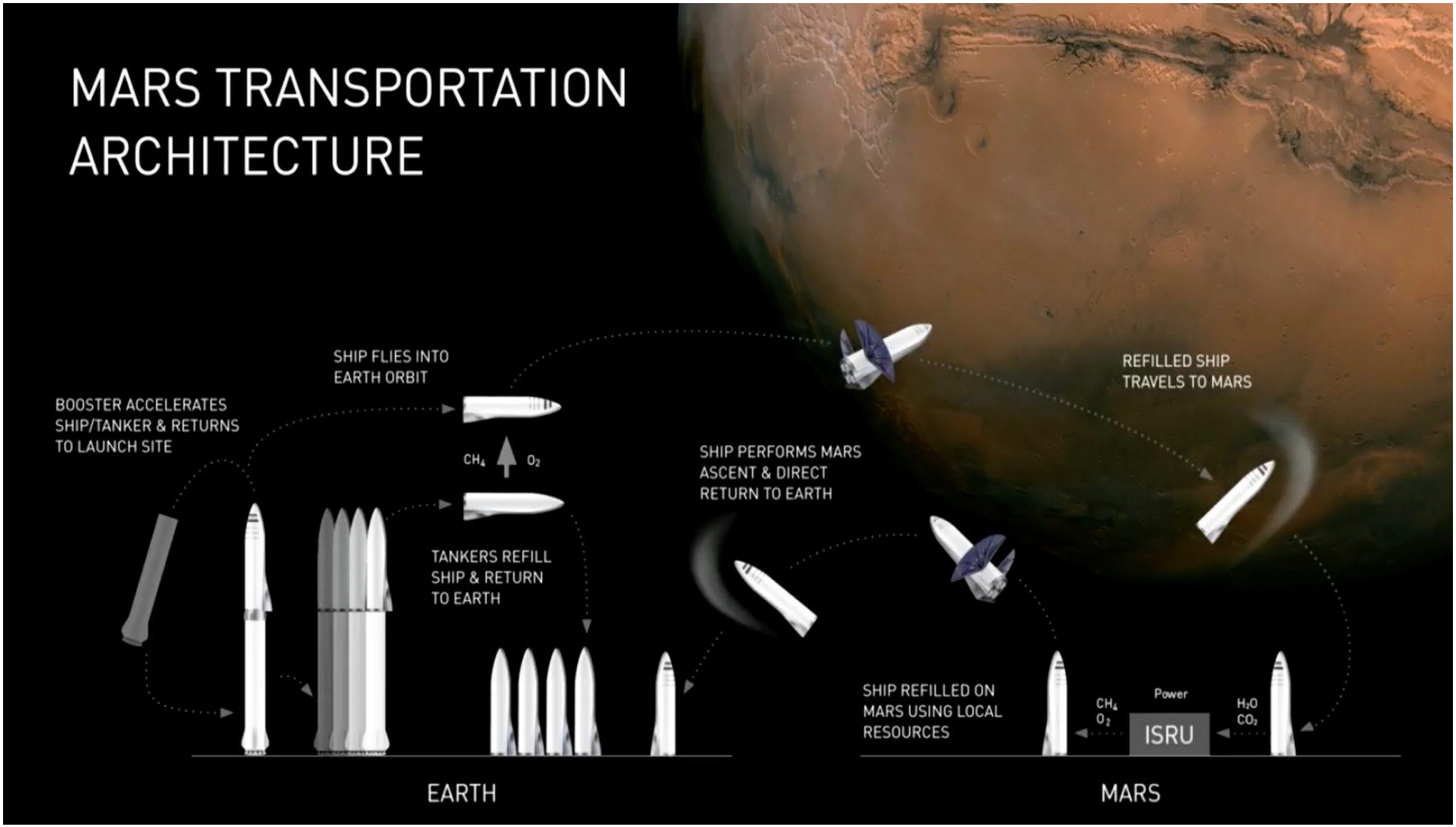
$$\Delta v = v_e \ln \frac{m_0}{m_f} = I_{sp} g_0 \ln \frac{m_0}{m_f}$$



To/From Lunar Surface
One-refuel



SpaceX Systems Approach (5 launches)



Comparison to Rockets - data varies greatly, only representative

Table 1: Launch Vehicle Delivery Percentages to GEO

Launch Vehicle	Pad Mass	To LEO (with % of pad)	to GEO (est.) (with % of pad)	to Moon surface (with % of pad)
Atlas V	590,000	18,500 (3%)	7,000 (1.2%)	
Delta IV H	733,000	28,770 (3.9%)	10,000 (1.4%)	
Falcon H	1,420,000	63,000 (4.4%)	26,000 (1.8%)	
Saturn V	2,970,000	140,000 (4.7%)		16,000 - 0.5%
average		4% of Pad mass	1.5% of pad Mass	

Note: data from web varies greatly - these numbers are representative only

Rough Numbers for Rockets:

Mass on the Pad	3,000,000 kg
Mass to LEO	120,000 kg
Mass insertion to GEO	45,000 kg
Mass to Lunar Surface	15,000 kg
Total Mass to Orbit 1957-2020	22,000,000 kg

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

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)

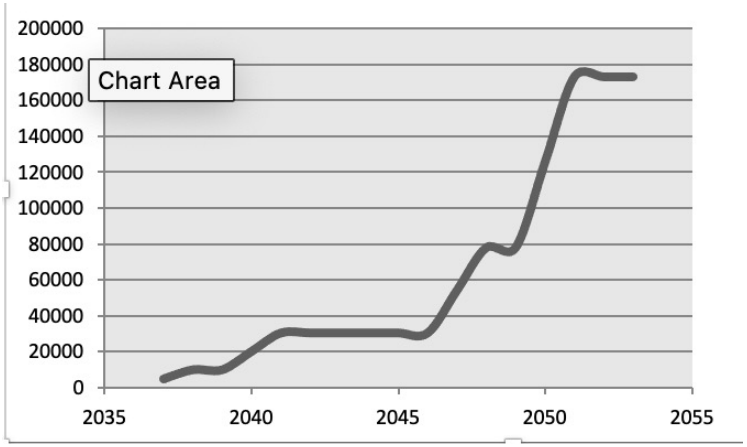
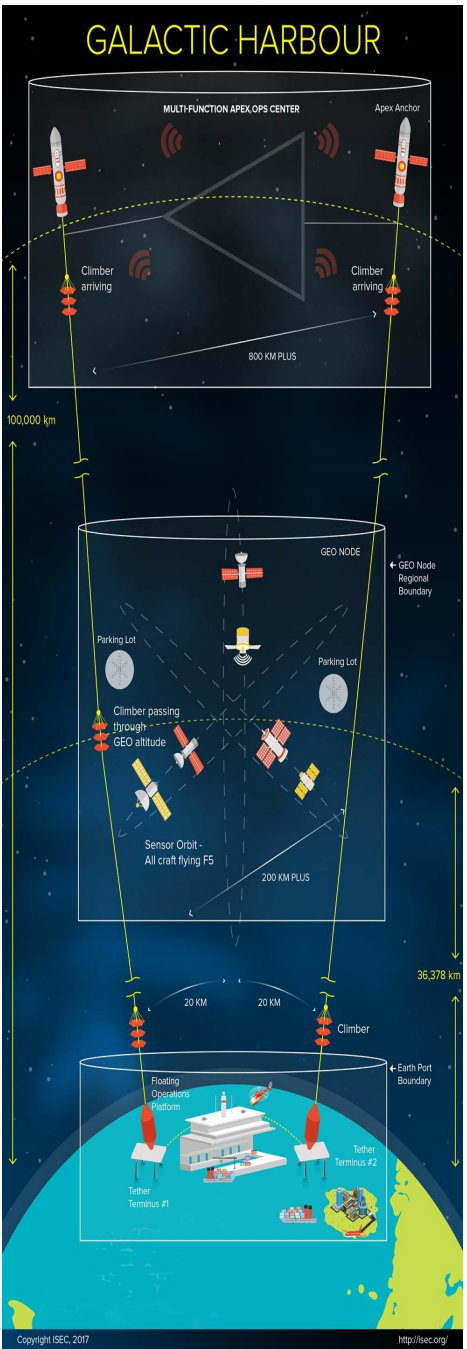
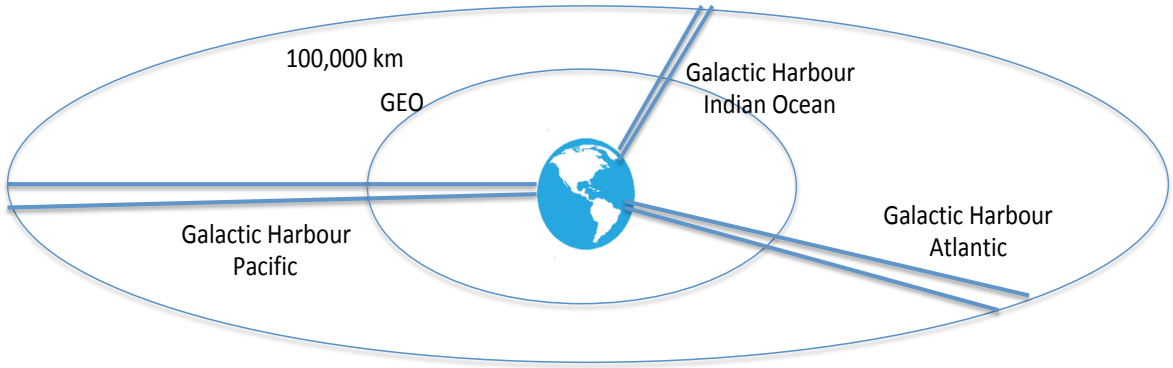


Figure 88. Massive Cargo Movement by Space Elevators (Swan "Dual Space Access Strategy Minimizes the Rocket Equation," Space Renaissance International 3rd World Congress 2021 – Congress Theses, Final Resolution and Papers. Pg 254-255.)

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)

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Space Elevator Vision 2038 Timeline

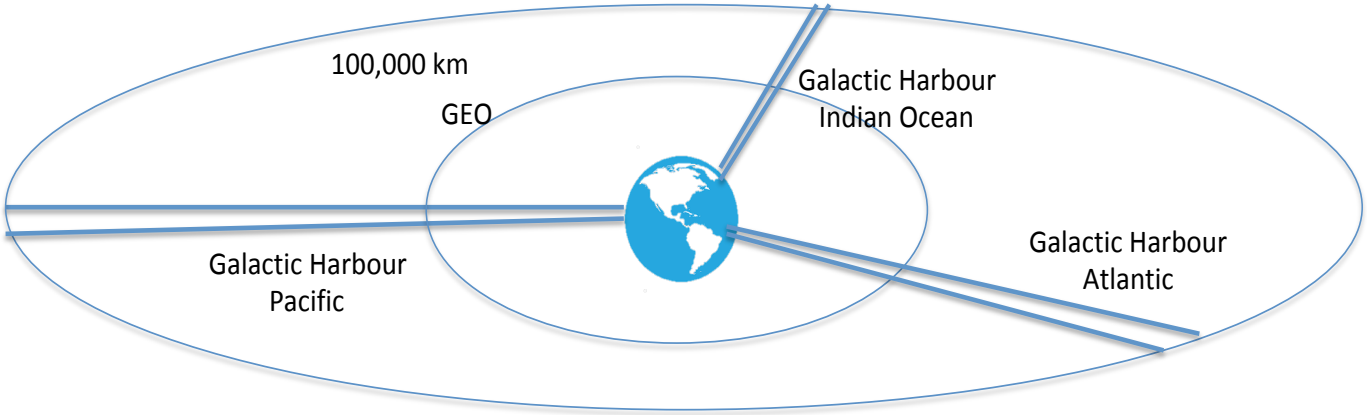
New Vision: *Space Elevators are the Green Road to Space while they enable humanity's most important missions by moving massive tonnage to GEO and beyond. This is accomplished safely, routinely, inexpensively, daily, and they are environmentally neutral.*

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

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

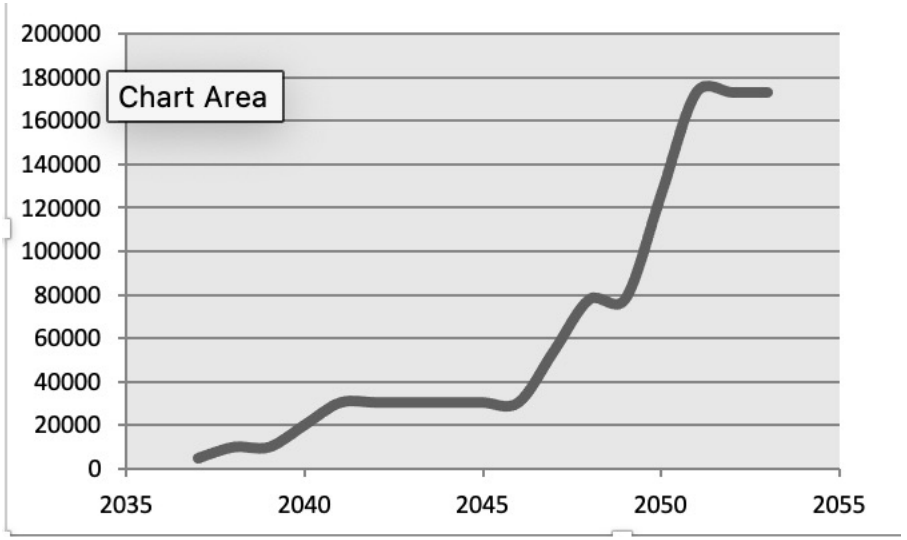
Three Galactic Harbours

– 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

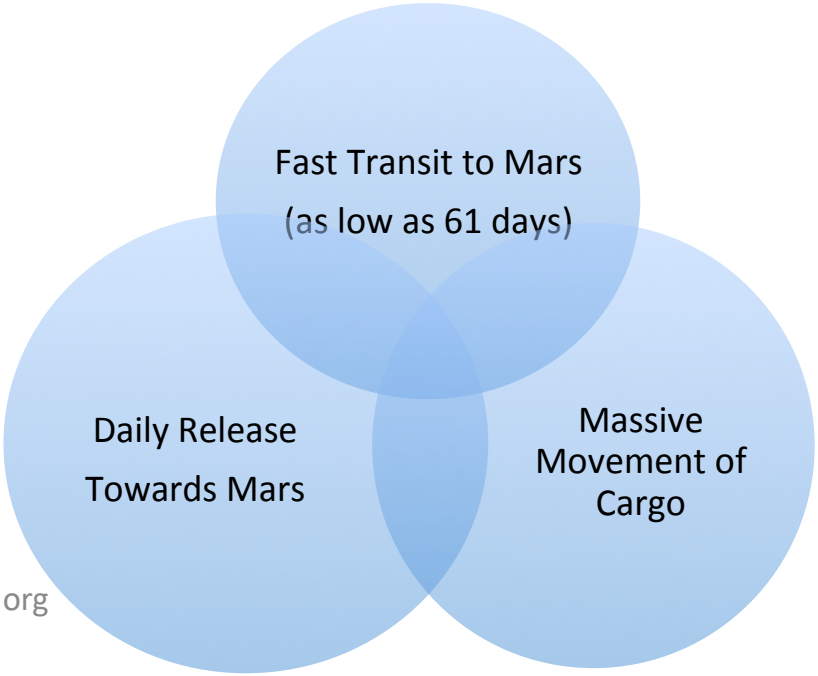
Annual payload (tonnes/yr)



Special Strengths
A New Concept

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 to Mars (61 days best with many 80 to 100 days)
- Release every day towards Mars (no wait for 26 month)
- Massive movement of mission support equipment (170,000 tonnes per year when system mature)



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:

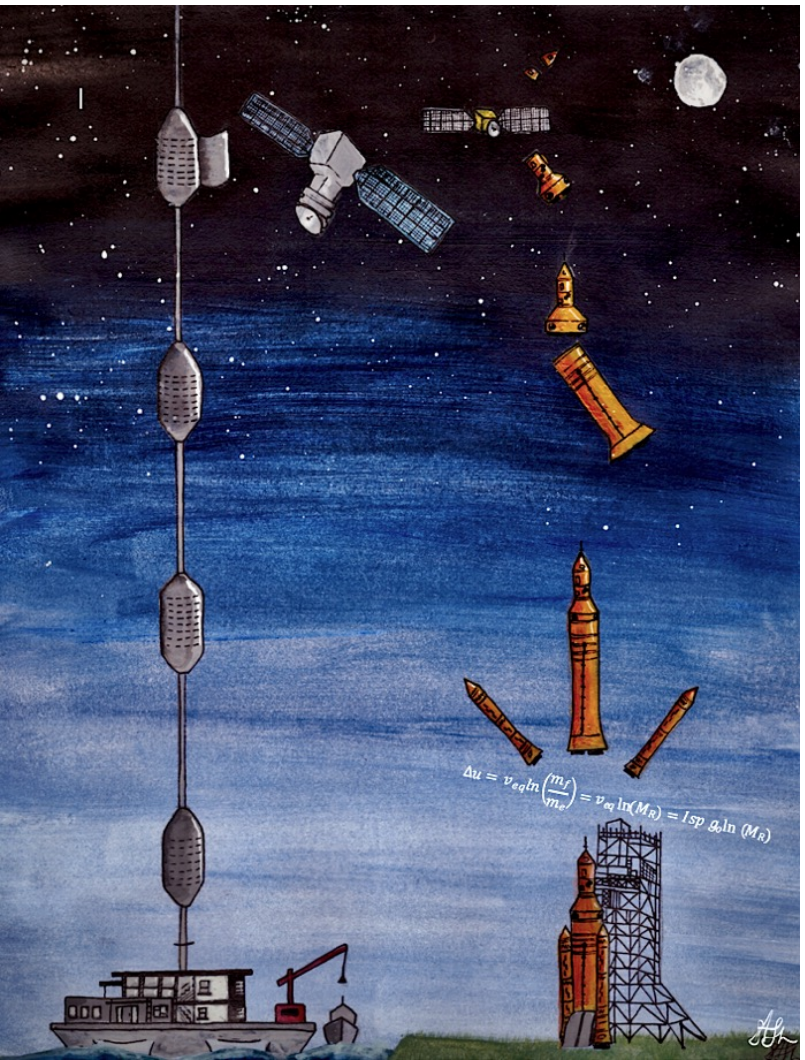
- Space Elevators are ready to enter Engineering Development (Phase Two of development)
- Space Elevators are the Green Road to Space
- Space Elevators can join advanced rockets inside a Dual Space Access Architecture
- Space Elevator’s major strength as a permanent transportation infrastructure is movement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

Art by
A. Stanton

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

Complementary Dual Space Access

- Revolutionary capabilities driven by the Starship will be dramatic, imagine future of mega rockets combined with the tremendous force multiplier the Space Elevator!
- Complementary benefits of Starship and Space Elevator working together will drive capabilities we are just beginning to imagine
  - Mass and size of payloads and equipment that can be delivered across our solar system will be liberated by these systems!
- Rockets are tremendously successful, can reach any orbit and can rapidly move people through radiation belts and to other planets.
  - Rockets are only able to launch a small percentage of their starting mass into orbit or other planets due to the energy required to get them there
- Space Elevators will have the ability to move massive cargo into GEO orbit or to the planets on a daily basis within inexpensive and environmentally friendly operations
  - The Space Elevator will not be good at placing payloads into LEO or MEO orbits but lucky for us Rockets are.
- Both systems are needed to be able to achieve the great visions of populating the Moon and Mars and beyond
  - We need to get people there and need logistics in place with continual replenishment to make these concepts work – Must embrace commercial Market Capabilities

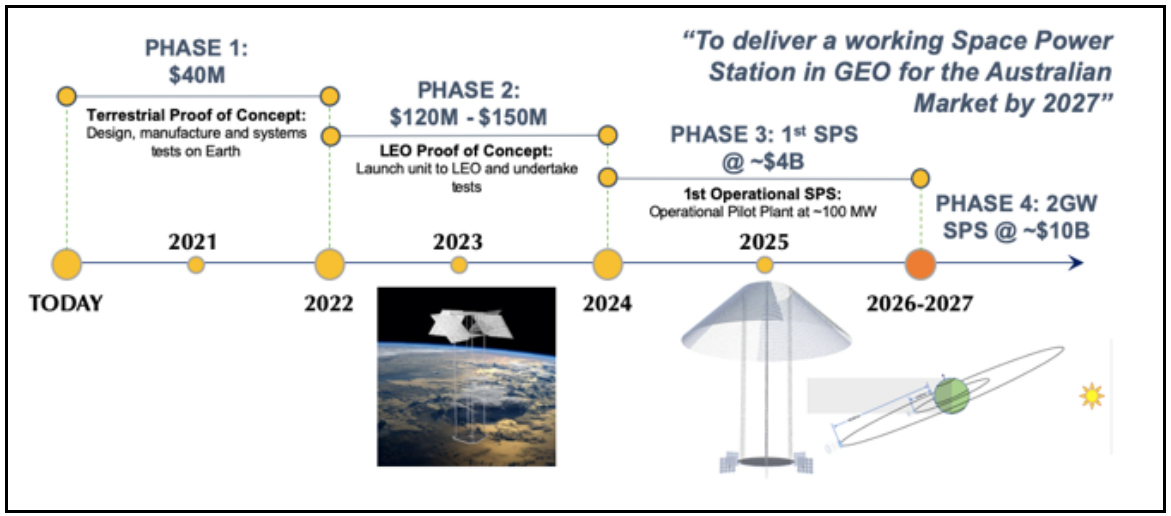
Complementary Dual Space Access

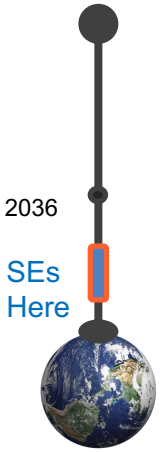
- Space industry will support and enable Artemis project goals to establish our presence on Moon
- Mr. Musk's vision of establishing humanity on Mars will be initiated
  - These two tremendous leaps forward for humanity and its ability to understand our neighborhood -Huge steps for humanity's ability to do colossal activities in space.
- Space Elevator is a must for humanity for so many reasons to encourage the research community to start thinking out of the box!
- Realm of science fiction has been surpassed as the Space Elevator has entered the second phase of development – Engineering Validation [2]
- Many missions screaming for more capability to orbit while the environmental community is concerned about thousands of launches around the globe per year
  - Space Elevators are going to help these dreams become realized in dramatic fashion - Massive cargo to high orbits and beyond for solar power system in space, mining asteroids, and settlements beyond LEO are just a few.
- Scientific community's assumptions have always included the restrictions of rockets
  - Mindset must change nto an aggressive approach to mega-rockets for ride sharing and then the future Space Elevators opening up the universe with assembly of massive science spacecraft at the top of the gravity well

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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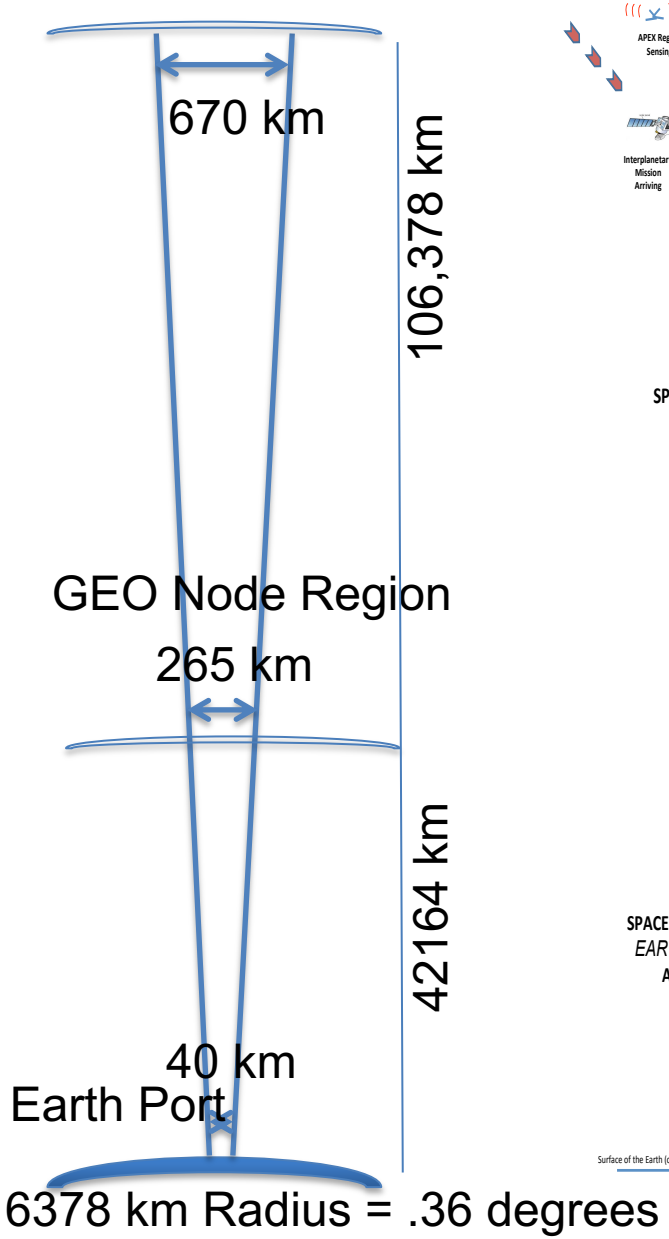
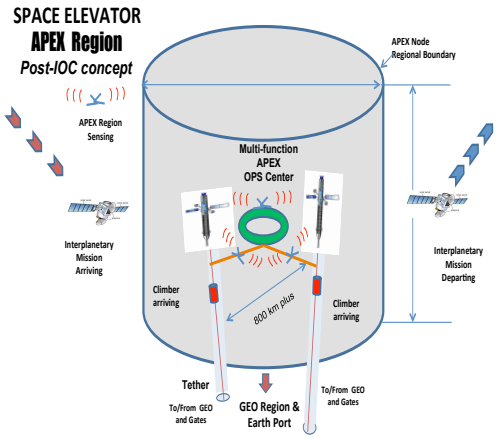
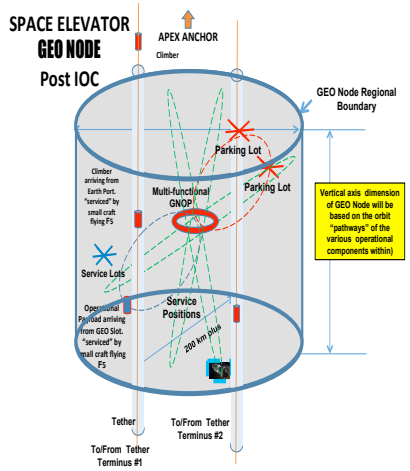
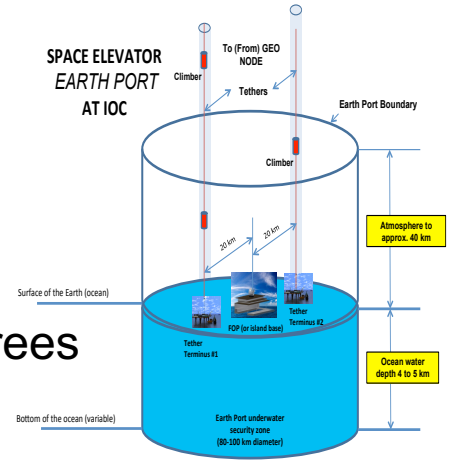


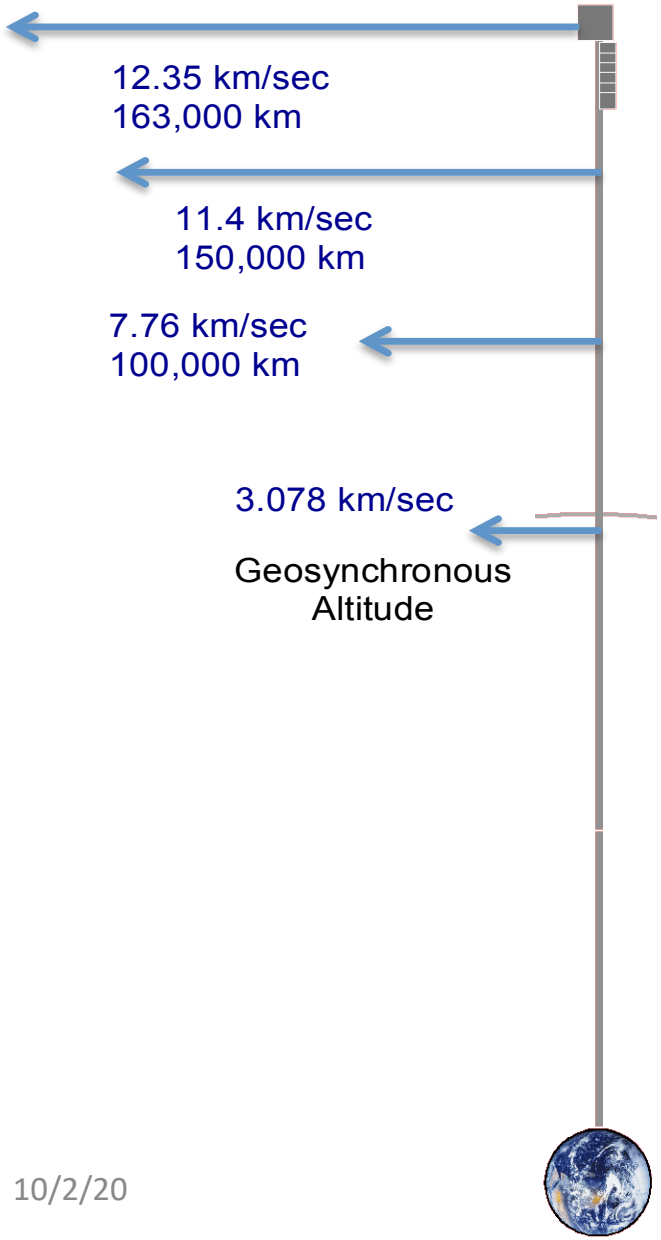






- Galactic Harbour includes two Space Elevators radially extending from Ocean surface to Apex Anchor for a permanent space access infrastructure.
- One reusable tether climber lift-off per day
- Three Regions, Earth Port – GEO – Apex Anchor, where commercial ventures will grow

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).

Agenda

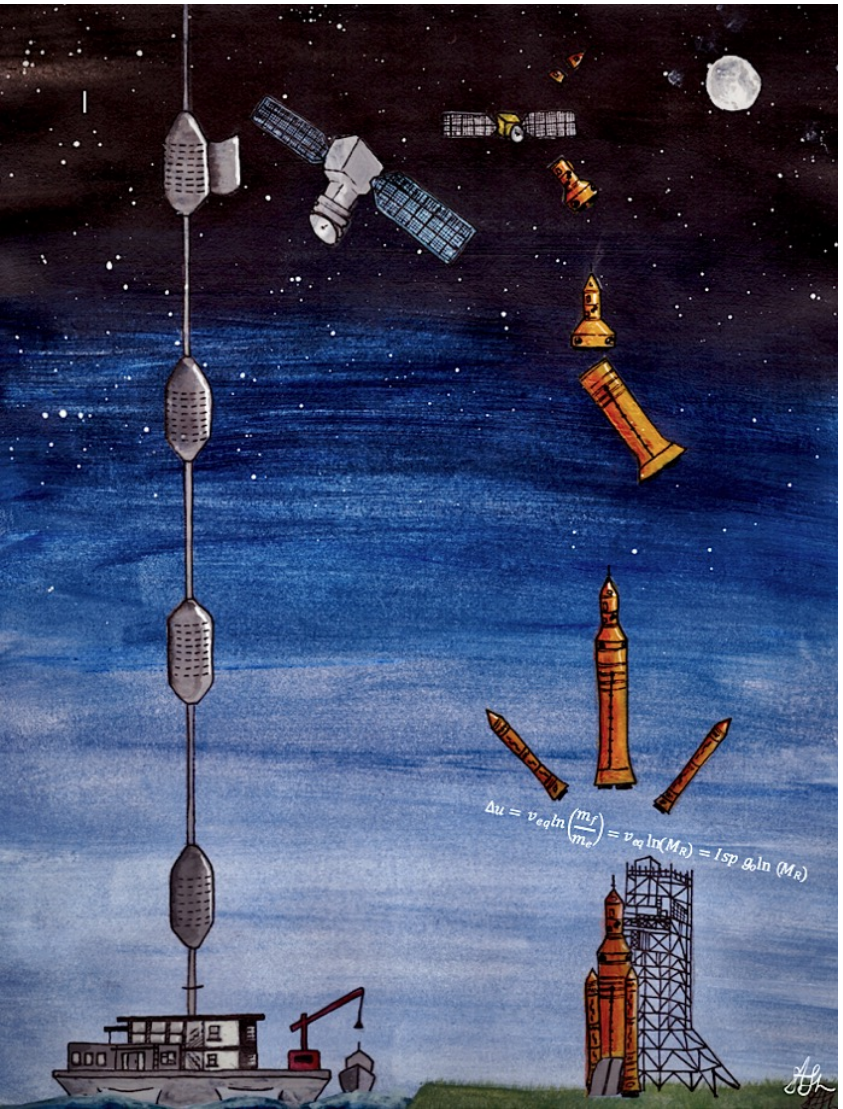
- Introduction
  - Historic Look
- Excitement for our future
  - Decadal Survey
  - Future Rocket Capability – Evolutionary Leap
  - Space Elevator Transformational Characteristics
- Dual Space Access Architecture
  - Advanced Rockets
  - Mars Study
- Assembly at Top of Gravity Well
  - Space Elevator Transportation Infrastructure
  - Apex Anchor Robotic Assembly
  - Range of Velocities
- Conclusions
  - Any Size – Any Mass – Every Day – Any Destination

Capacity available to go to the Moon, Mars, and beyond will simply be unmatched

- Emerging capabilities, initially provided by Artemis and Starships, and then Space Elevator will enable allocated funds to go farther – Cheaper launch!
  - In short term - likely difficult to obtain greater funding levels for scientific exploration
  - With decreased cost of launch and design flexibility, can fund more Science! Current number of scientific missions should be expanded!
  - PRISM and CLPS programs allow scientists to get their Lunar science accomplished by submitting an instrument proposal - Need programs with similar characteristics to quickly select new missions elsewhere
- Time is NOW for NASA to fight for more budget in anticipation of the opportunities Artemis, Starship and Space Elevator will provide
- Requires Quicker selection processes to pick new missions to match increased capacities - These should be planned in advance to be prepared!

Requires – More Rapid/Flexible
Payload Selection/Funding Mechanisms

Why Space Elevators? Because we Must!

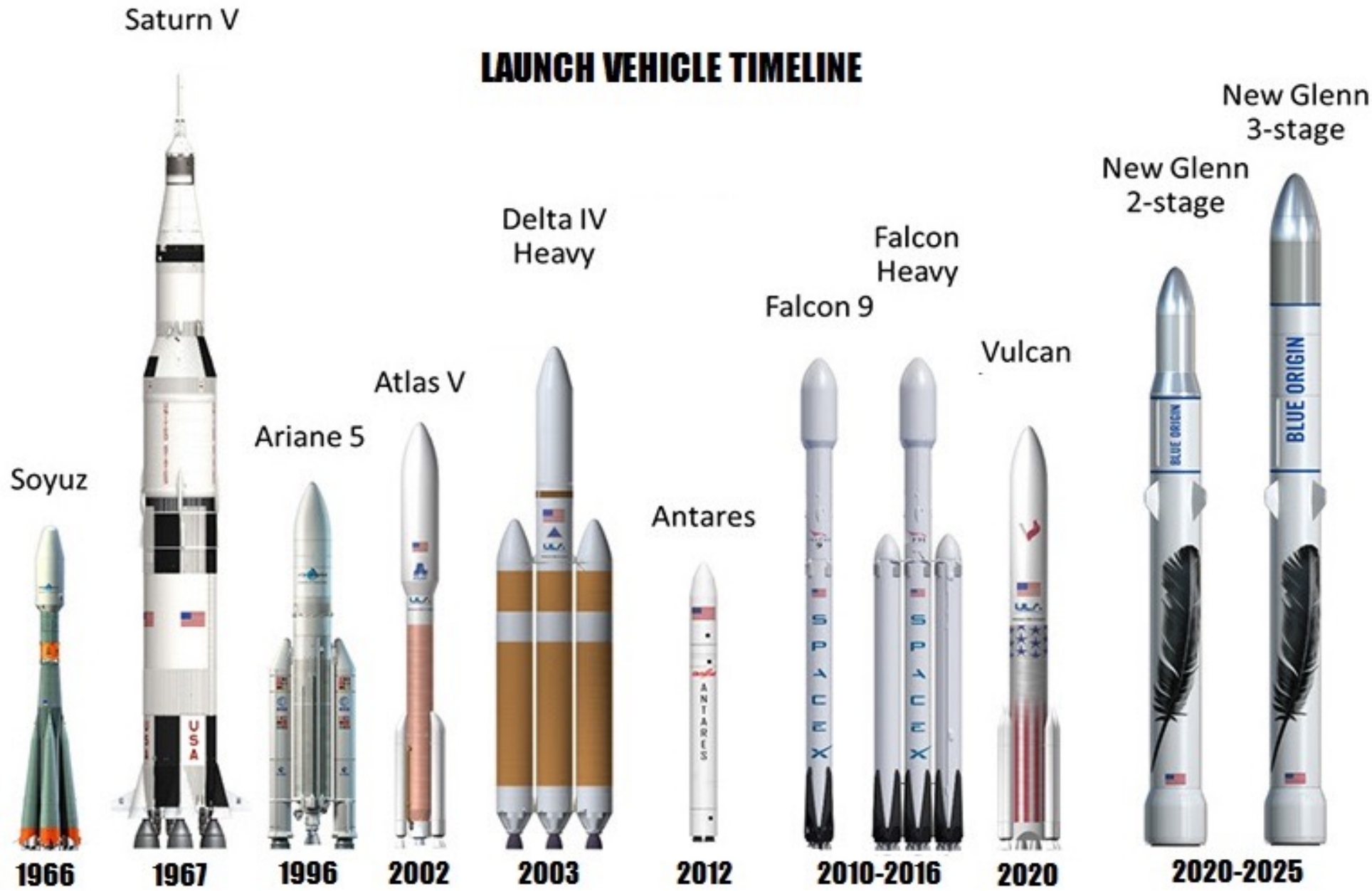


- Fulfills the Dreams of Many
- Raises Massive Cargo using Solar Energy
  - Green Road to Space
  - Permanent Infrastructure for GEO & Beyond
  - Daily, Routine, Safe, and Inexpensive
  - Early Operations: 30,000 tonnes per year
- Space Elevators are a Simple Elegant Solution to the Rocket Equation.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

Questions and Answers

NASA Image, USA Today,


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

Comparison to Rockets - data varies greatly, only representative

Table 1: Launch Vehicle Delivery Percentages to GEO

Launch Vehicle	Pad Mass	To LEO (with % of pad)	to GEO (est.) (with % of pad)	to Moon surface (with % of pad)
Atlas V	590,000	18,500 (3%)	7,000 (1.2%)	
Delta IV H	733,000	28,770 (3.9%)	10,000 (1.4%)	
Falcon H	1,420,000	63,000 (4.4%)	26,000 (1.8%)	
Saturn V	2,970,000	140,000 (4.7%)		16,000 - 0.5%
average		4% of Pad mass	1.5% of pad Mass	

Note: data from web varies greatly - these numbers are representative only

Rough Numbers for Rockets:

Mass on the Pad	3,000,000 kg
Mass to LEO	120,000 kg
Mass insertion to GEO	45,000 kg
Mass to Lunar Surface	15,000 kg
Total Mass to Orbit 1957-2020	22,000,000 kg

Number of Rocket Launches per year
= 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

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		22216	568650

Note: Leo is 4% of launch pad mass

GEO, Interplanetary, Lunar 2% of pad

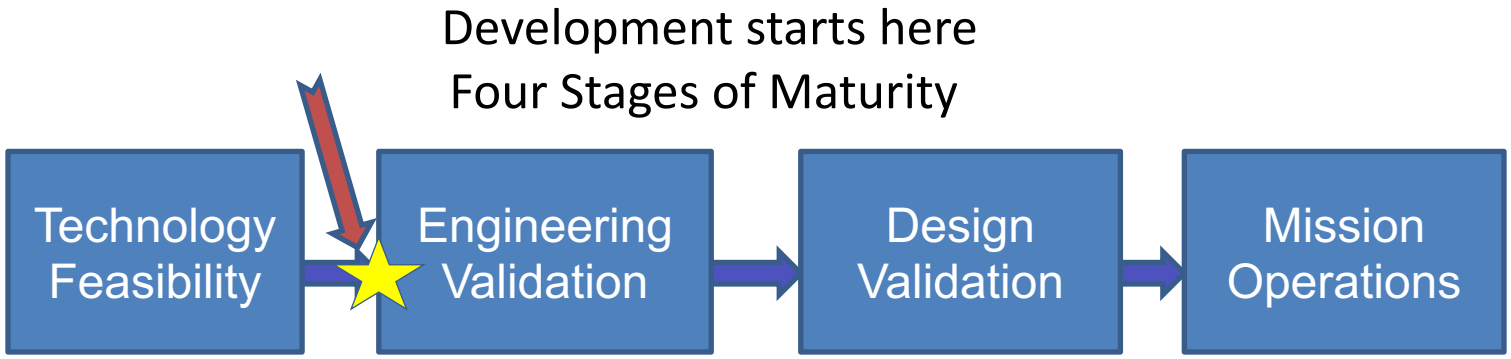
*note: Shuttle was a launch vehicle itself, but gained orbit, so mass to orbit

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

Multiple Visions

- National Space Society (US) - "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." (since 70's and Princeton Academic Course – L5 Colony)
- The British Interplanetary Society mission – To promote the exploration and use of space for the benefit of humanity.
- Mr. Bezos - "millions of people living and working in space" or maybe: "I am going to build the road to space."
- Mr. Musk – "Making Humanity Multiplanetary"
- NASA - With the Artemis program, NASA will land the first woman and next man on the Moon by 2024, using innovative technologies to explore more of the lunar surface than ever before.
- ESA - "This MoU marks a critical point in Europe's trajectory: it confirms we are going forward to the Moon, not just in terms of equipment and technology, but also with our people. Europe will play a central role in the new era of global space exploration along with NASA and our partners, delivering exemplary, game-changing architectures to explore the Moon and Mars and inspiring generations to come." (Mr. Wormer 28 Oct 2020)

The Space Elevator has Entered 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 developmental 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.

Space Elevator Roadmap

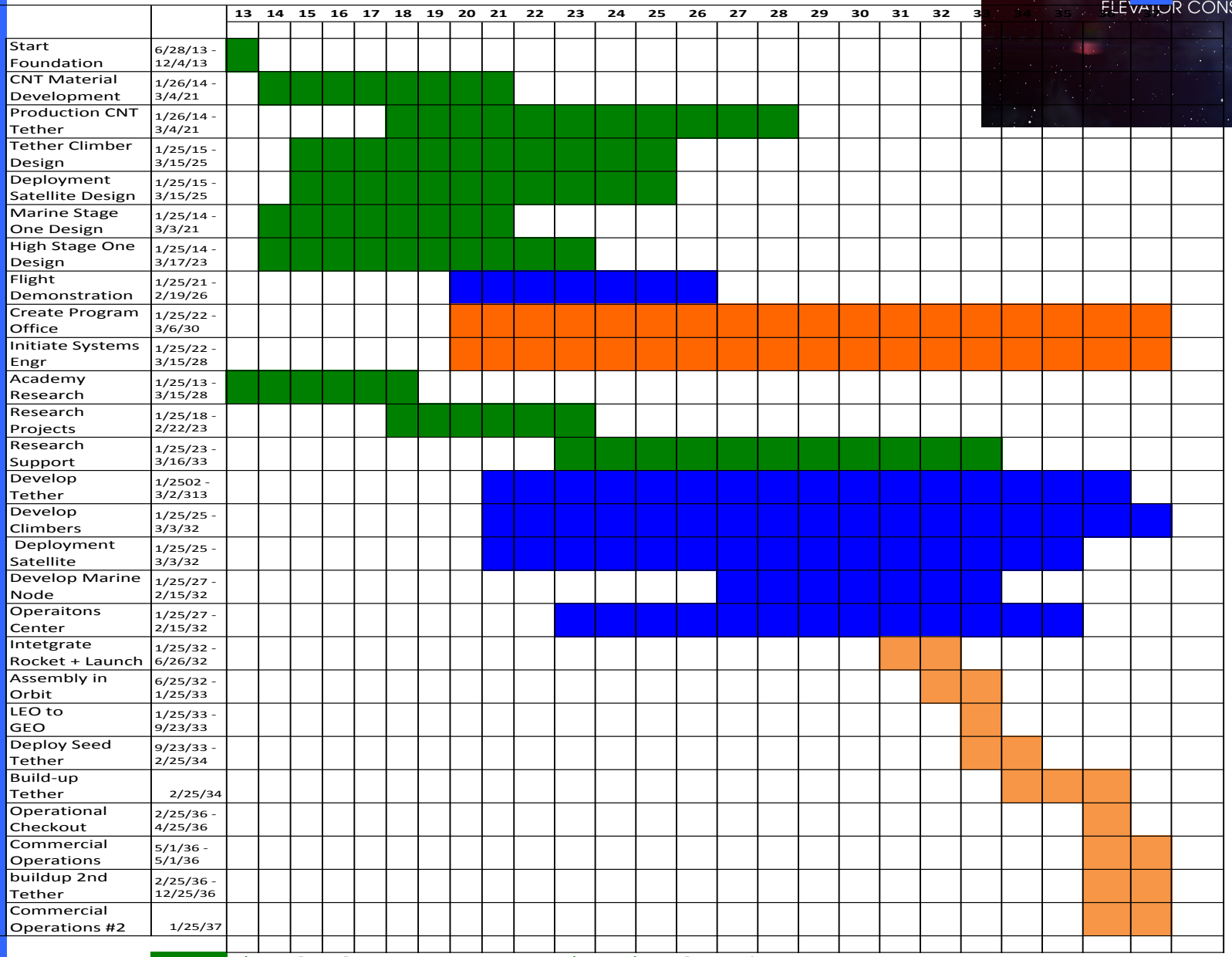


Figure 11- 1. Space Elevator Roadmap A