Today's Space Elevator

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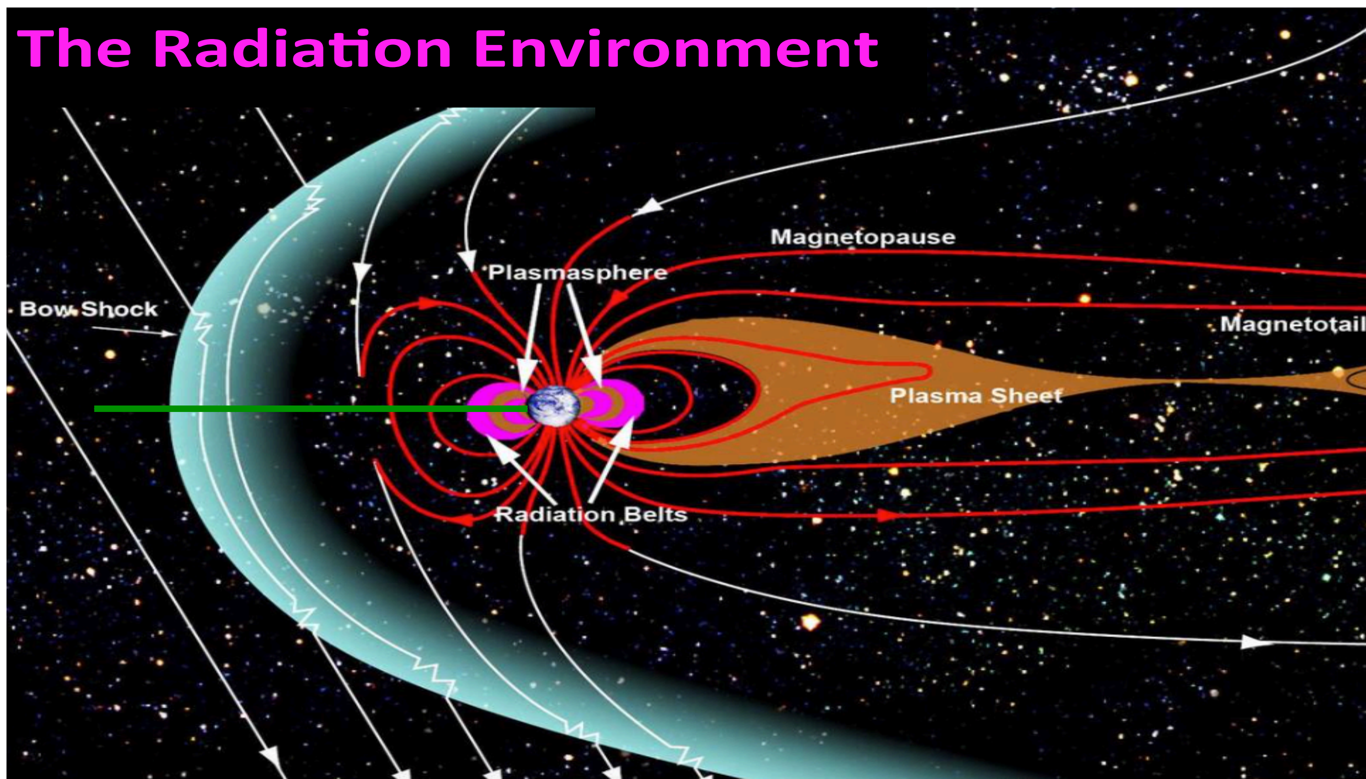
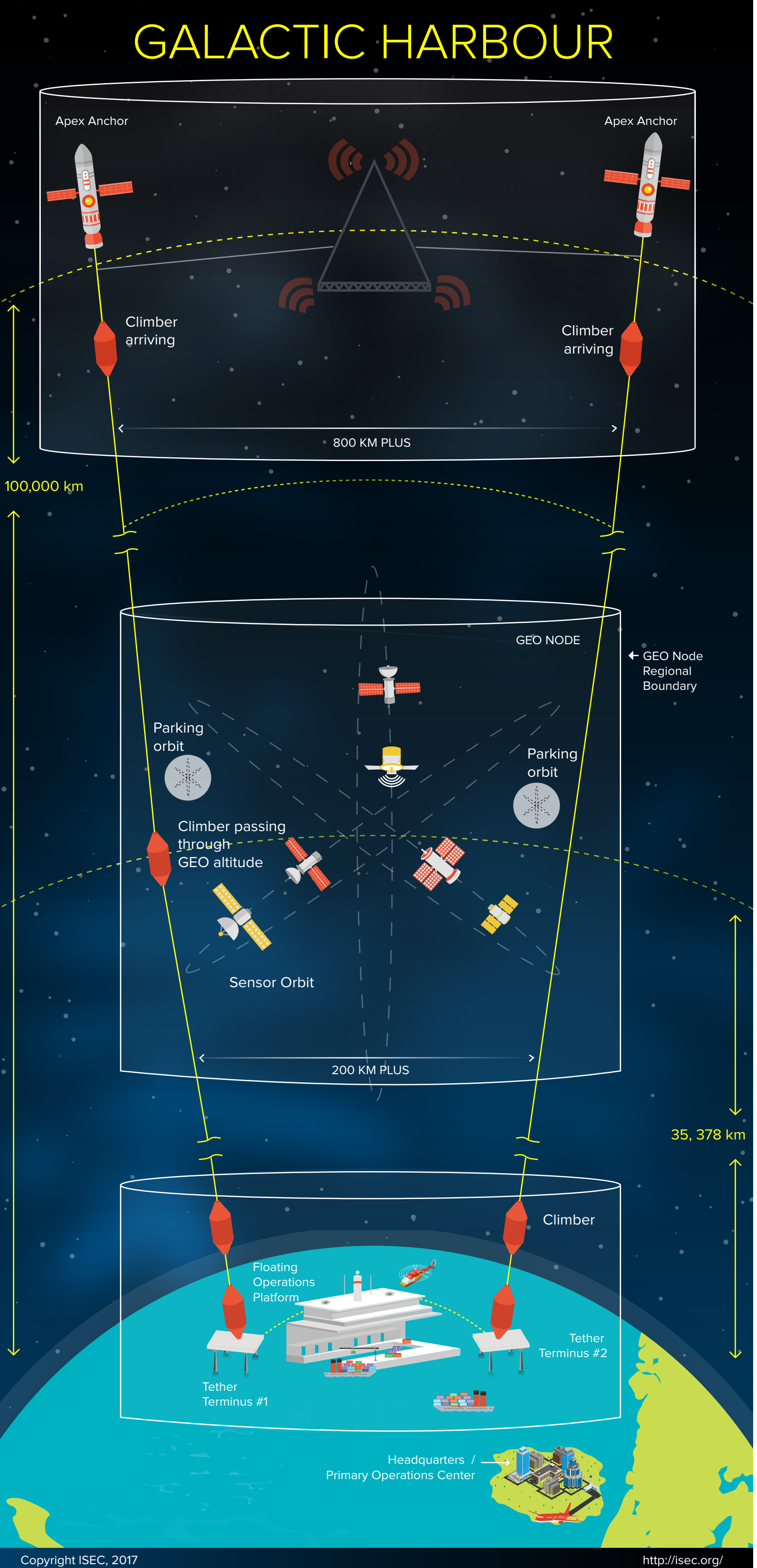
Earth Radius
6,378 Km

Space
Elevator
100,000 km
In green





INTERNATIONAL SPACE ELEVATOR CONSORTIUM

ISEC

Today’s Agenda

Introduction

Where is the Space Elevator Today?

Tether Material

Engineering Development

Where are We?

Conclusion

Galactic Harbours will Unify Transportation and Enterprise Throughout the Regions.

Space Elevator Strengths

- Routine [daily] access to space
- Revolutionarily inexpensive [<$100 per kg] to GEO and beyond
- Commercial infrastructure development similar to bridge building
- Permanent infrastructure [24/7/365/50 years]
- Massively re-usable, no consumption of fuels
- Environmentally sound/sustainable - will make Earth "greener"
- Safe (low risk) and reliable [no shake, rattle and roll of rocket liftoff]
- Low probability of creating orbital debris
- Redundant paths as multiple sets of Space Elevators become operational
- Massive loads per day [starts at 14 metric tons cargo loads]
- Opens up tremendous design opportunities for users
- Optimized for geostationary orbit altitude and beyond
- Co-orbits with GEO systems for easy integration

Vision of the Galactic Harbour Piers

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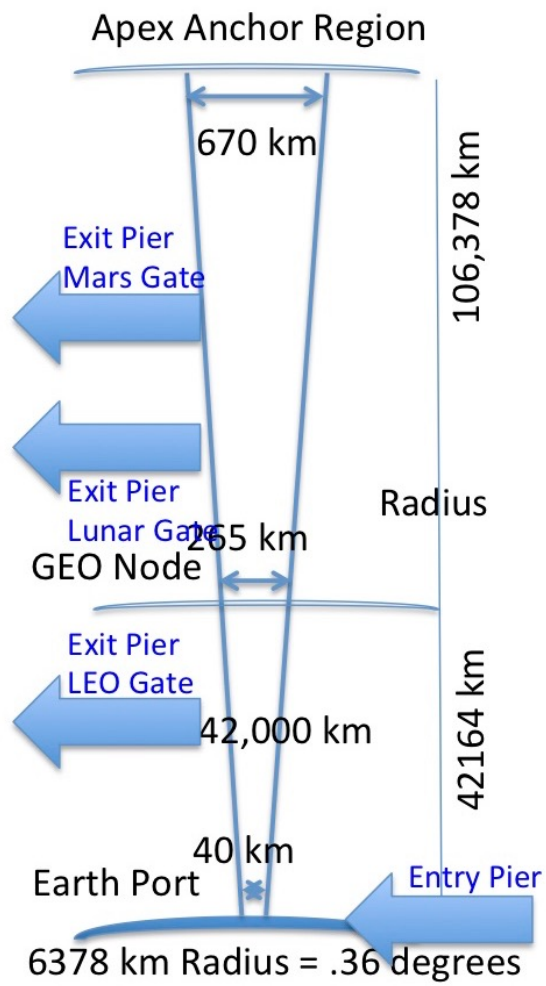
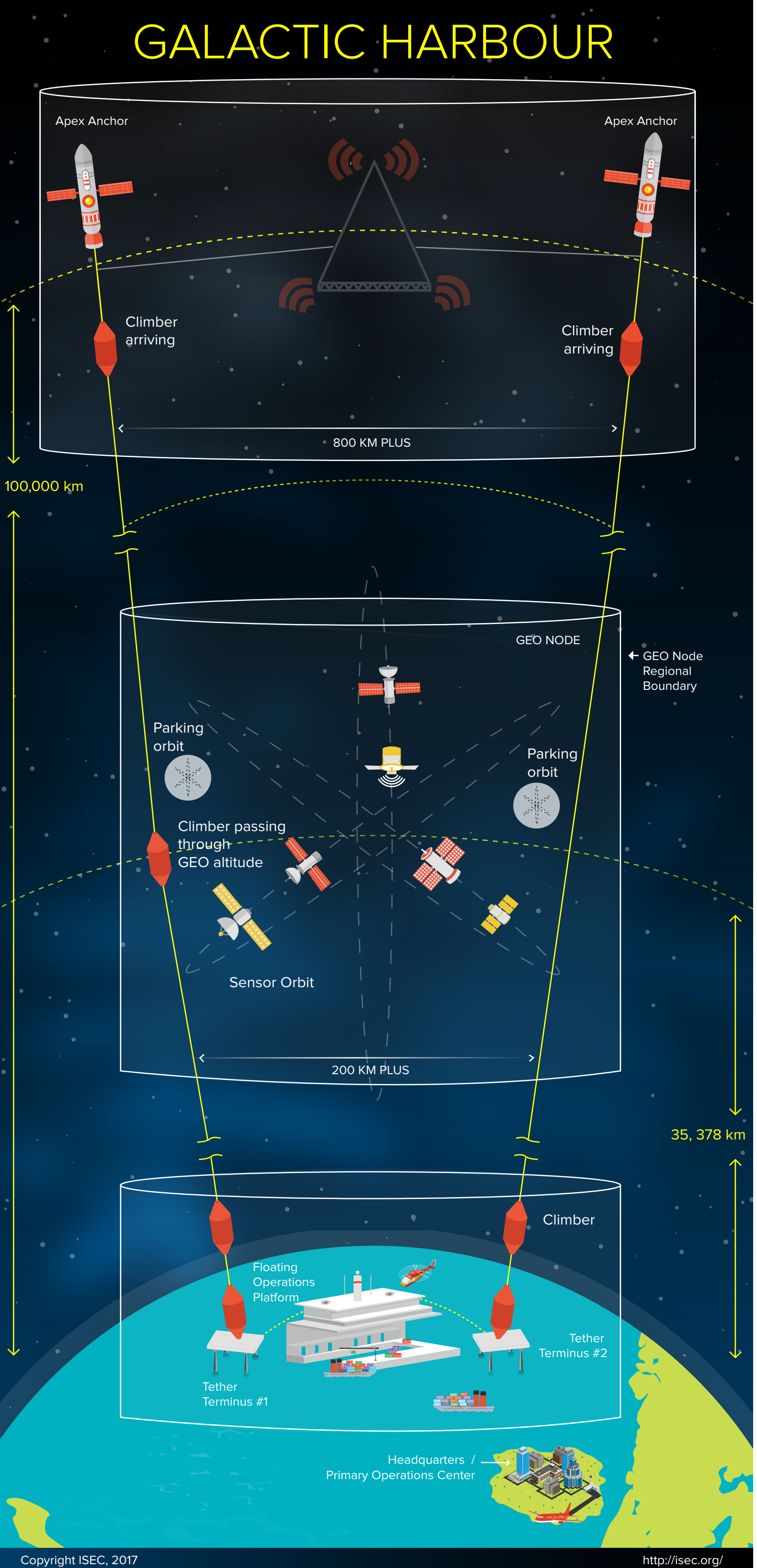
- *Space Elevator Transportation System serves as the 'main channel' in the Galactic Harbour.*
- *Businesses access the main channel from the Earth Port, the GEO Node, and the APEX Region.*
- *Businesses flourish as part of the Space Elevator Enterprise System*

Galactic Harbour The Unifying Vision





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2019 Breakout Year

- This phase change in Space Elevators has several elements, to include movement from:
  - Space Elevator to Galactic Harbour
  - Wishing for a material for the tether to having one successfully tested
  - An immature plan to a preliminary positive assessment of each technology within
  - each system segment
  - Quiet discussions in small groups to advocacy across the world.

Case for Space Elevators

Point One: Space Elevator Transportation Infrastructure - if you ship 100 tons of mission support equipment from the Earth Port; 100 tons show up in proper orbit. No rocket equation eating up launch pad mass.

Point Two: Interplanetary Mission Support - Departs daily from Apex to Mars (no 26-months wait between launch windows) with rapid transit (77 days best time) plus other solar-system destinations.

Point Three: Inexpensive, routine, and environmentally friendly daily departures from the Galactic Harbour's Earth Port.

Point Four: Single Crystal Graphene shows remarkable potential as tether material, half meter single molecule already made in the lab in 2D form.

The Space Elevator will be the

transportation story of the 21st Century!

Major Studies
IAA & ISEC

Year	Study Title	Organization
2020	Interplanetary Mission Support (in development)	ISEC
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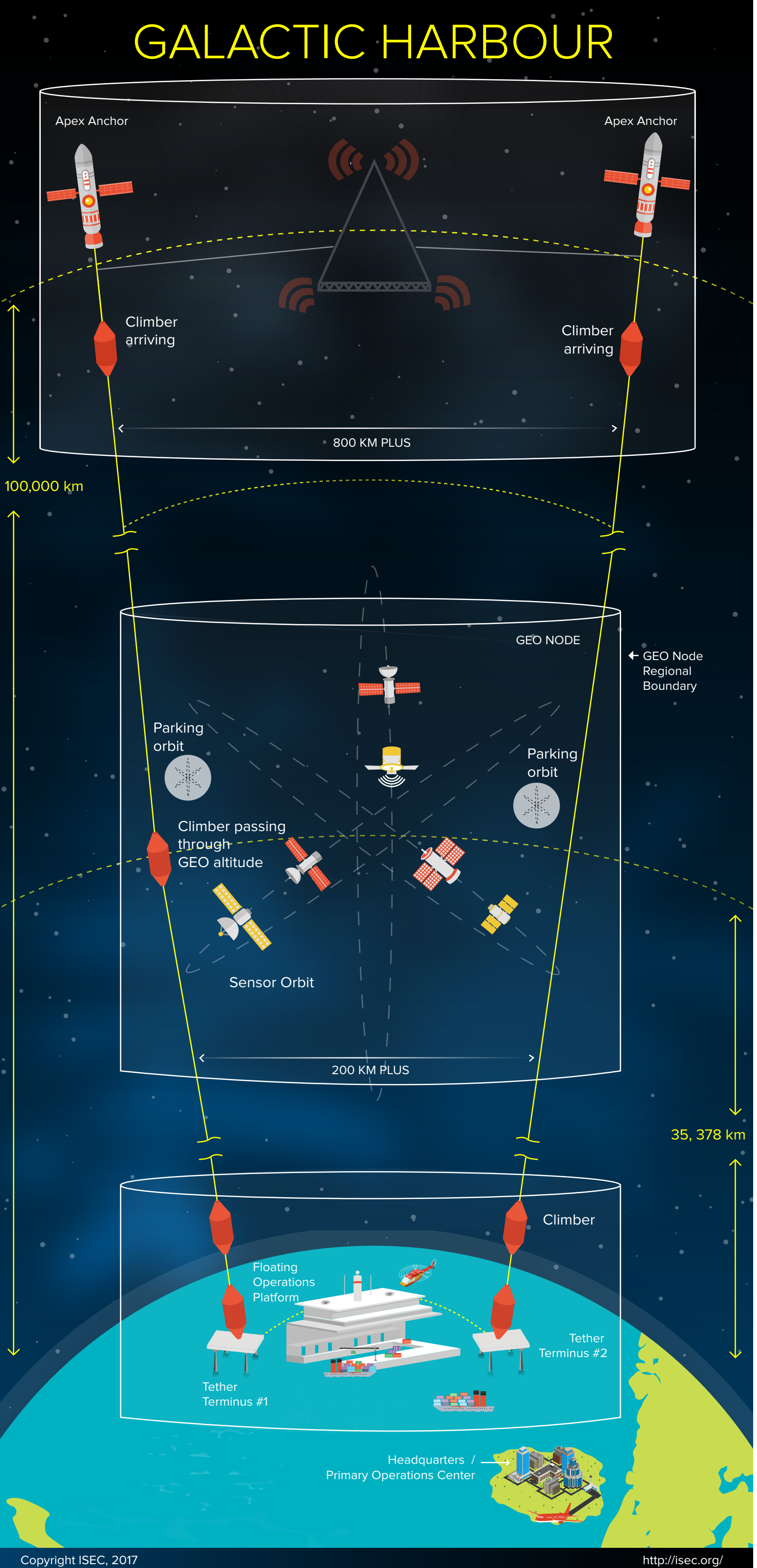
Note: IAA - International Academy of Astronautics: ISEC - International Space Elevator Consortium

In addition, the Obayashi Corporation conducted a major study on space elevator design with published results. Ishikawa, 2013.



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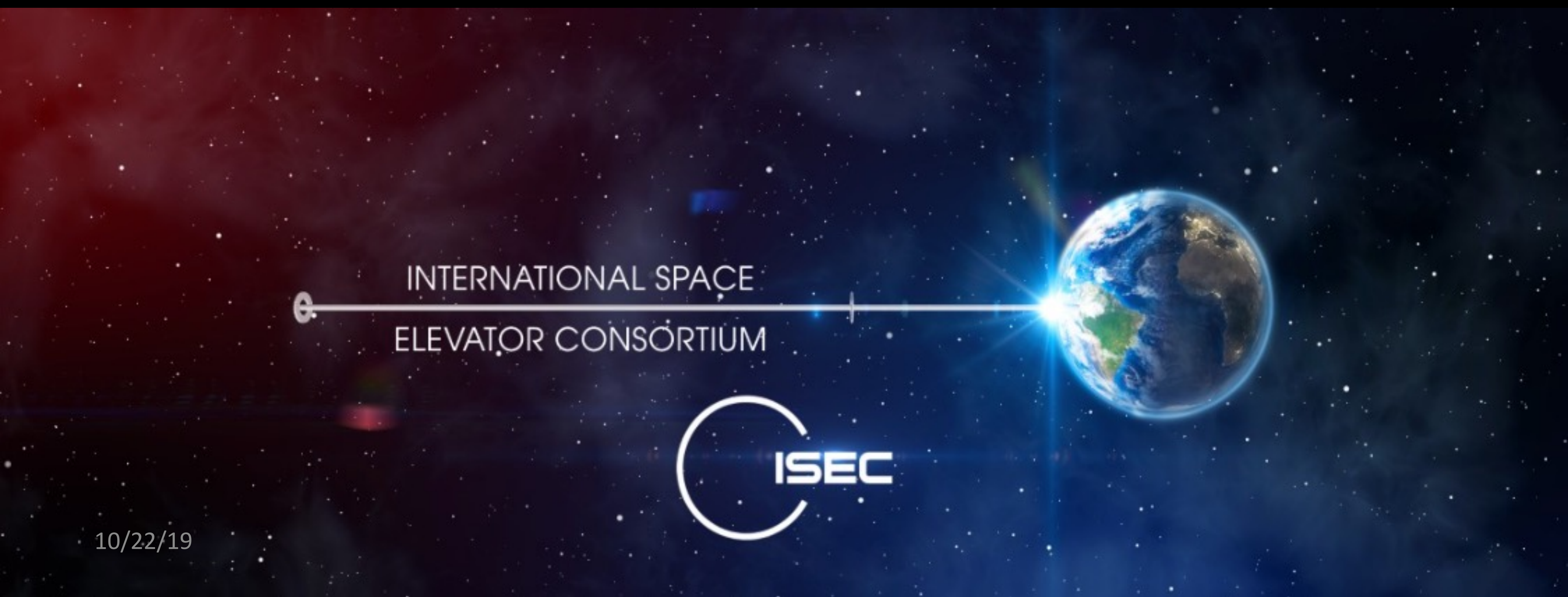
The last piece of the puzzle?

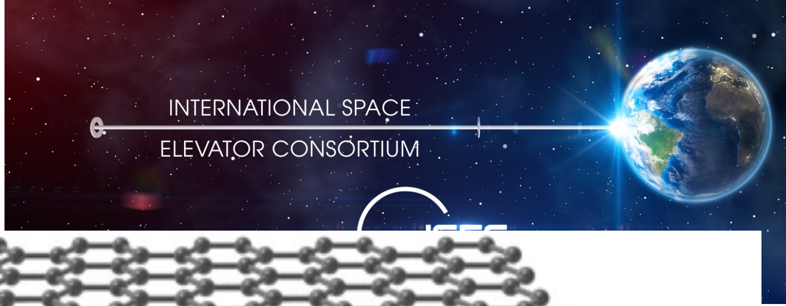
Graphene

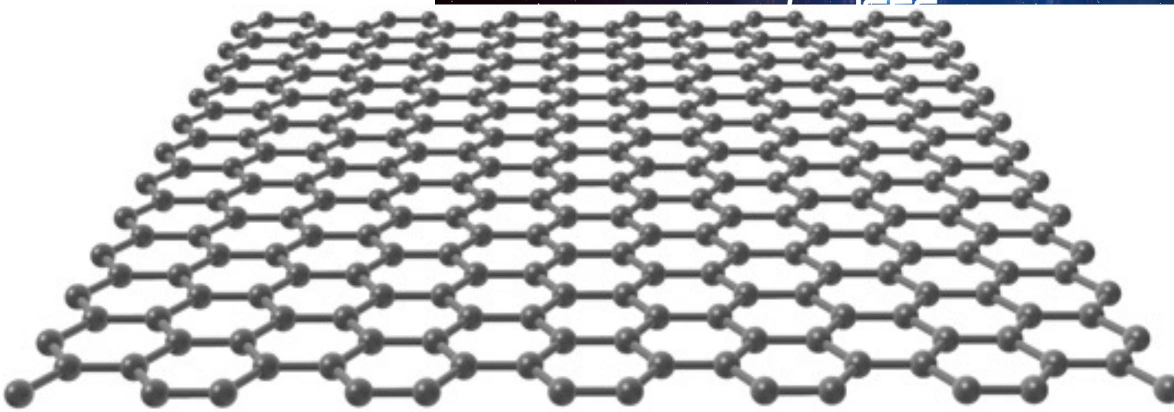
Adrian Nixon

15th June 2019

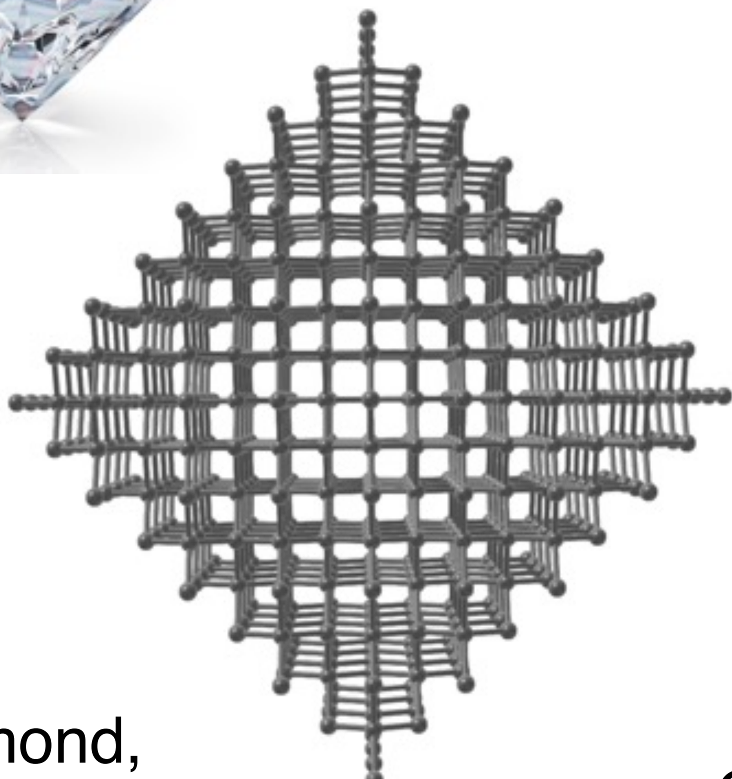


The carbon family

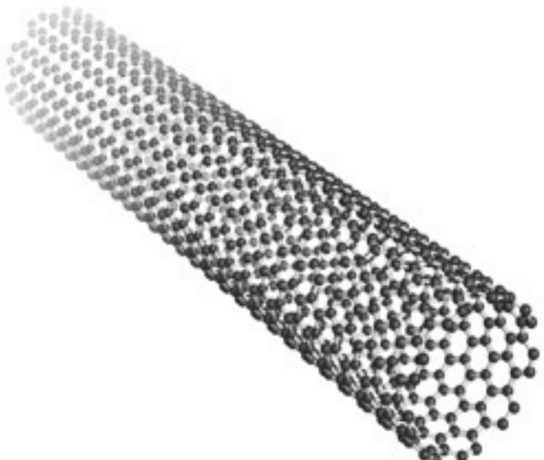




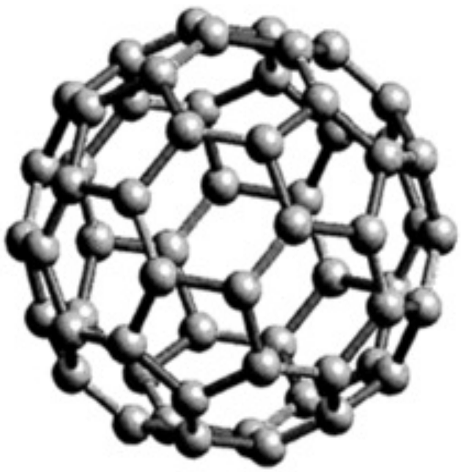
Graphene:
2D material



Diamond,
Amorphous Carbon:
3D material



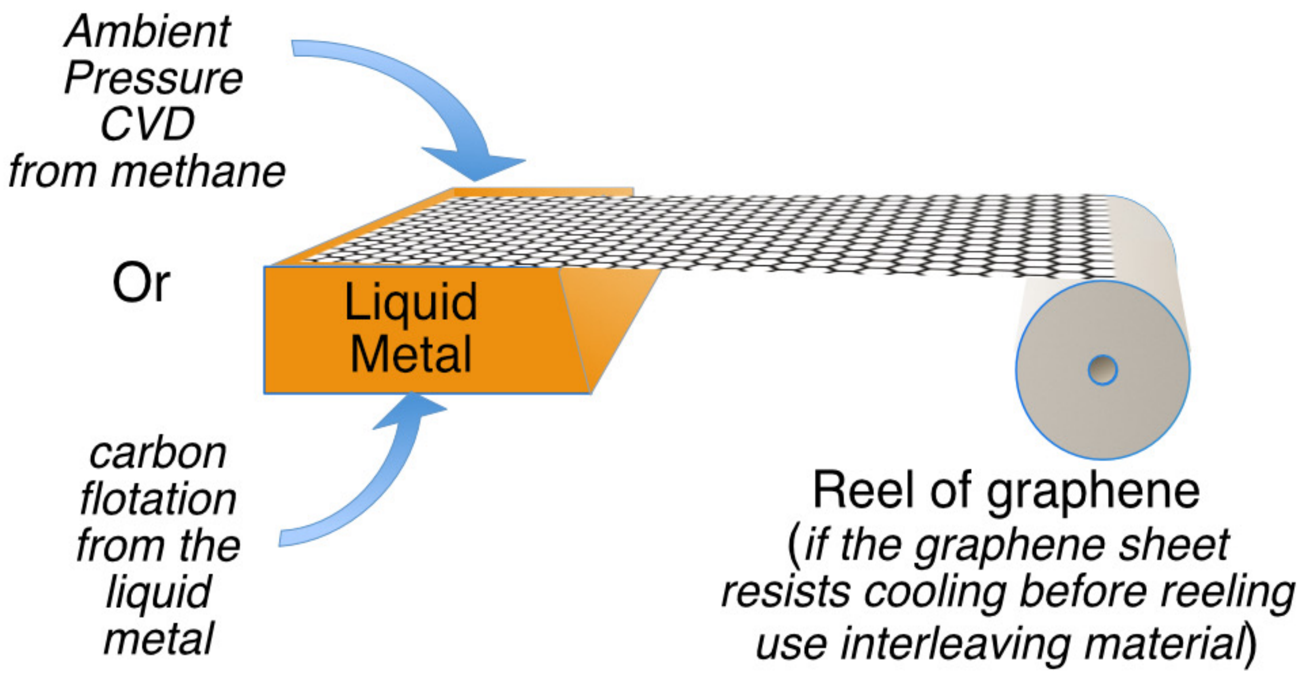
Carbon nanotubes:
1D material



Fullerenes:
0D material

Graphene: A new continuous process

Principles for making continuous single crystal sheet graphene



I published the hypothesis to test it amongst the world's top graphene scientists. (While retaining key intellectual property)

This hypothesis has not been invalidated to date.

https://investorintel.com/market-analysis/making-graphene-2d-materials-liquid-

Tether candidate materials

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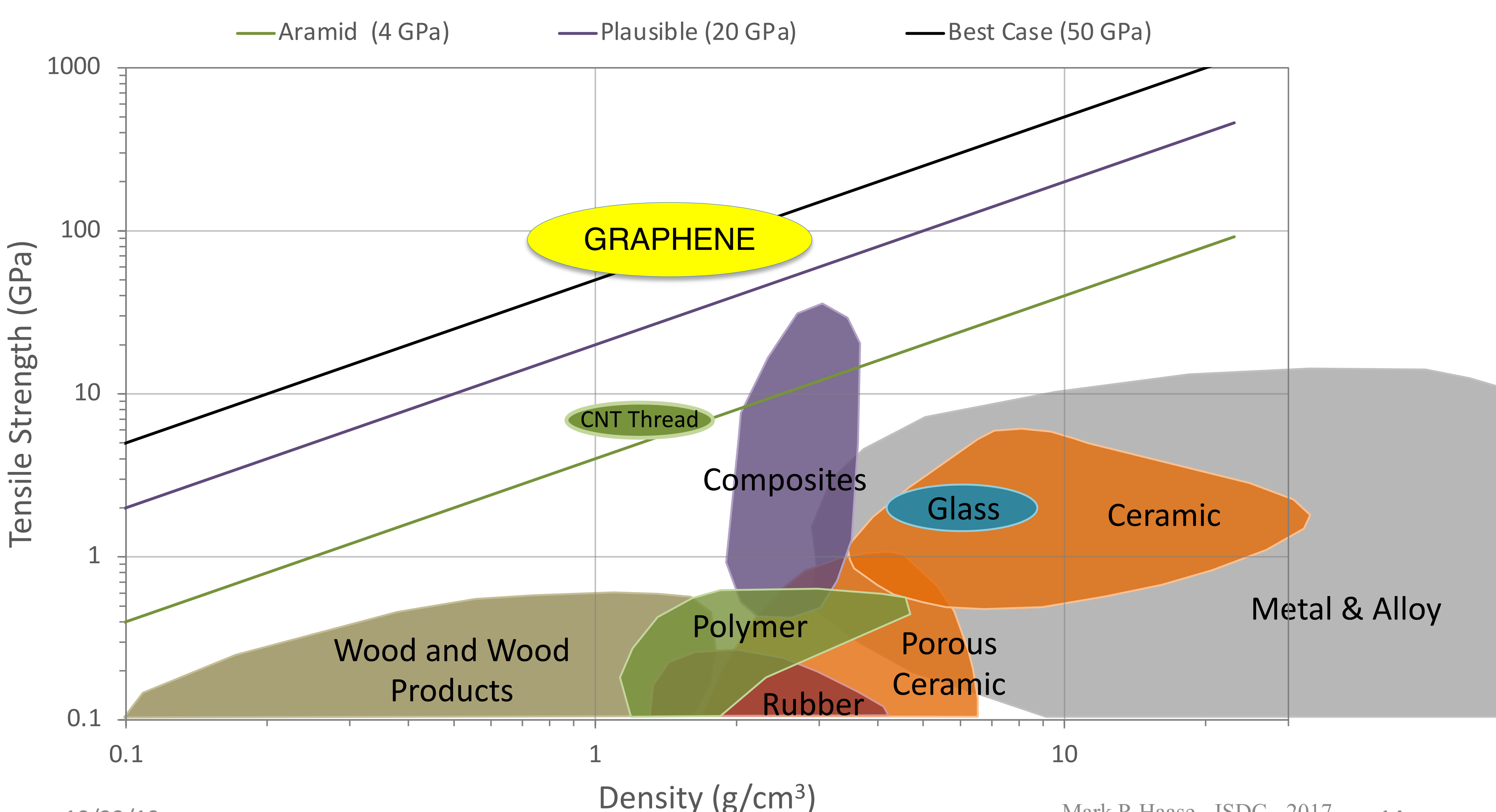
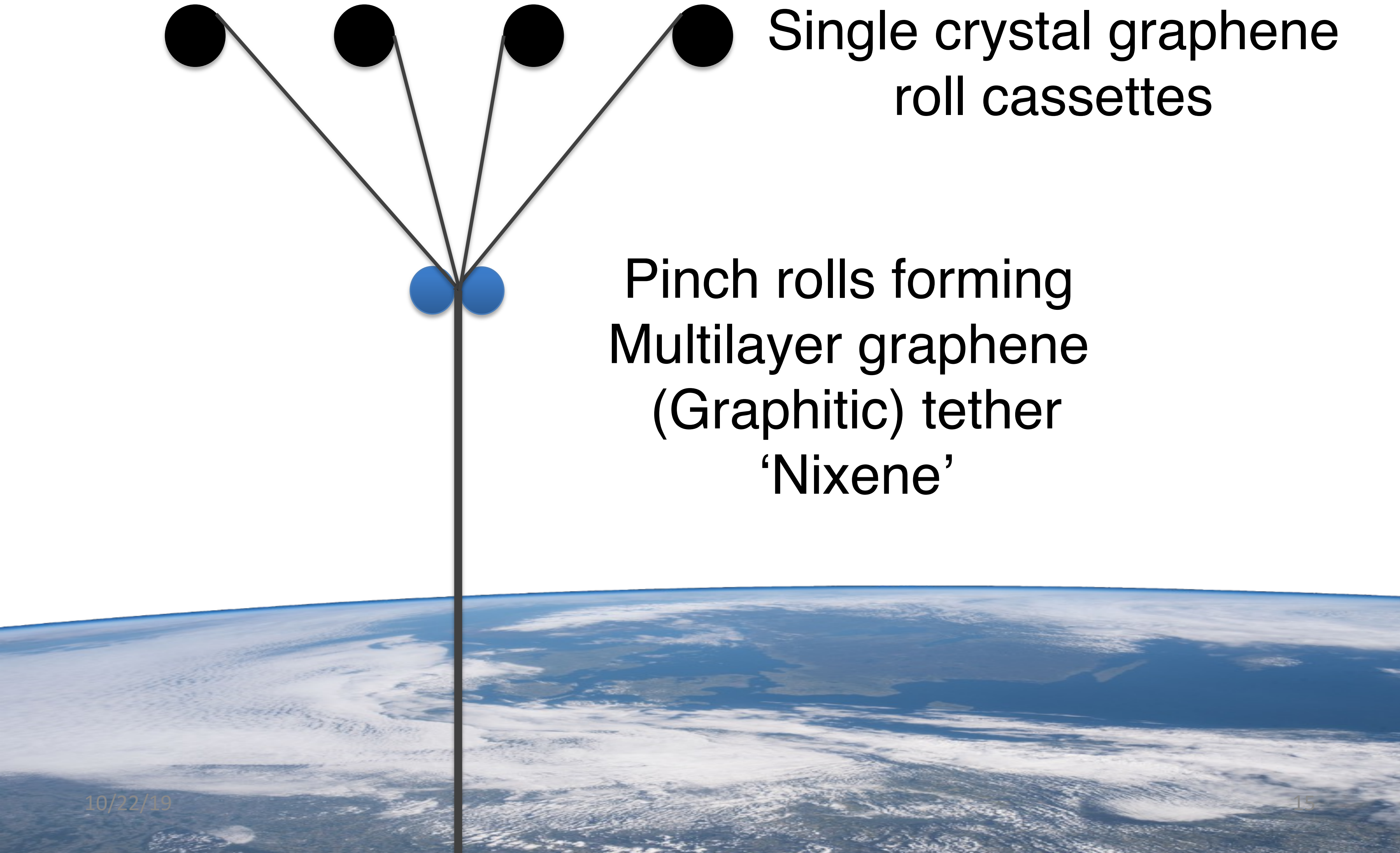
YES: Graphene is strong enough to be a candidate tether material



Combine the tether layers in orbit…



Is a tether made from single crystal graphene feasible?

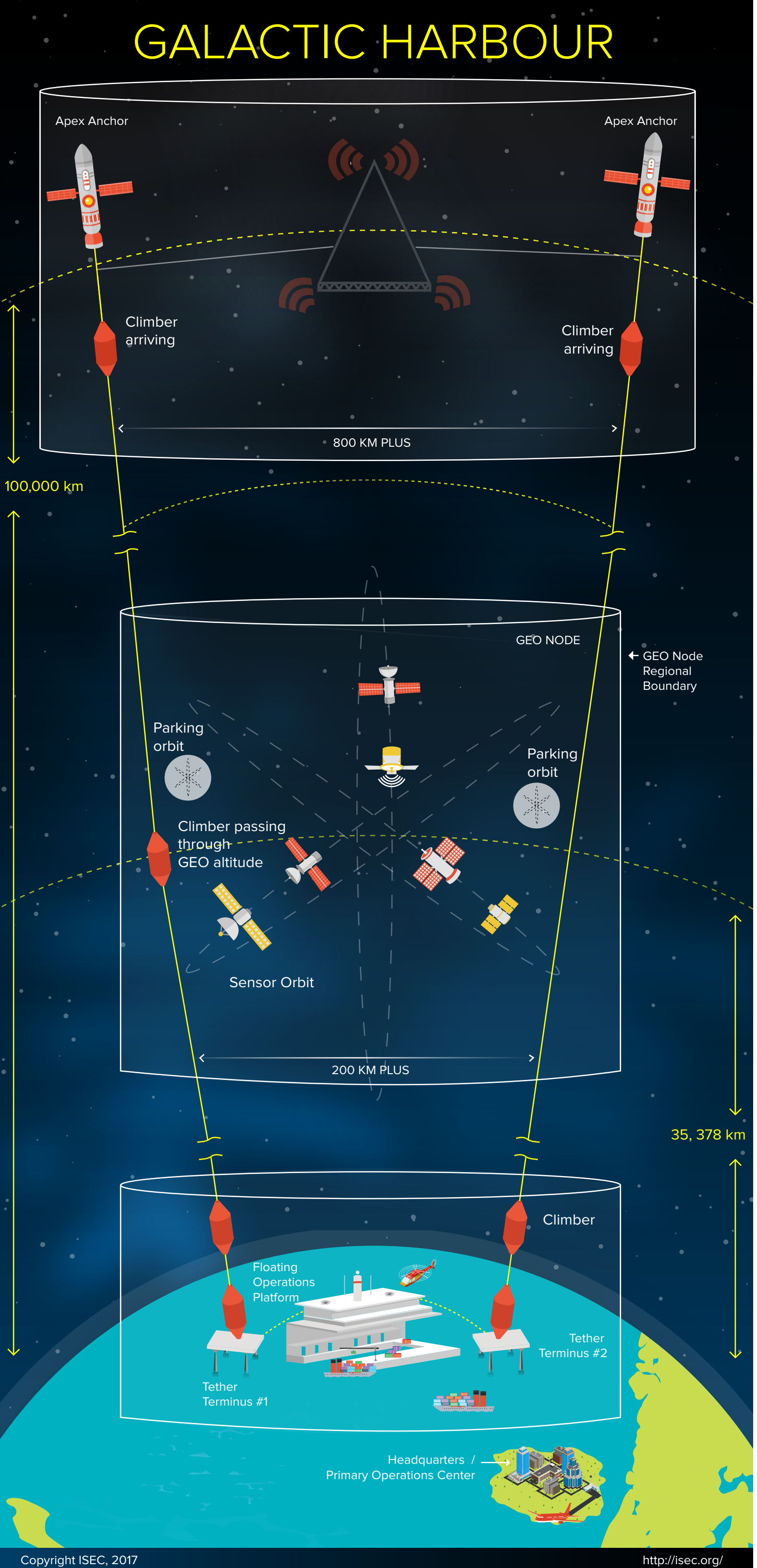
Current commercial nanoplate graphene cannot be used to make a tether.

However, 500mm of single crystal graphene has been made 13 years after graphene first isolated.

Layered single crystal graphene is yet to be made but we know how to do this and the material is already being called Nixene

YES

Graphene tether material really is possible within our lifetimes.



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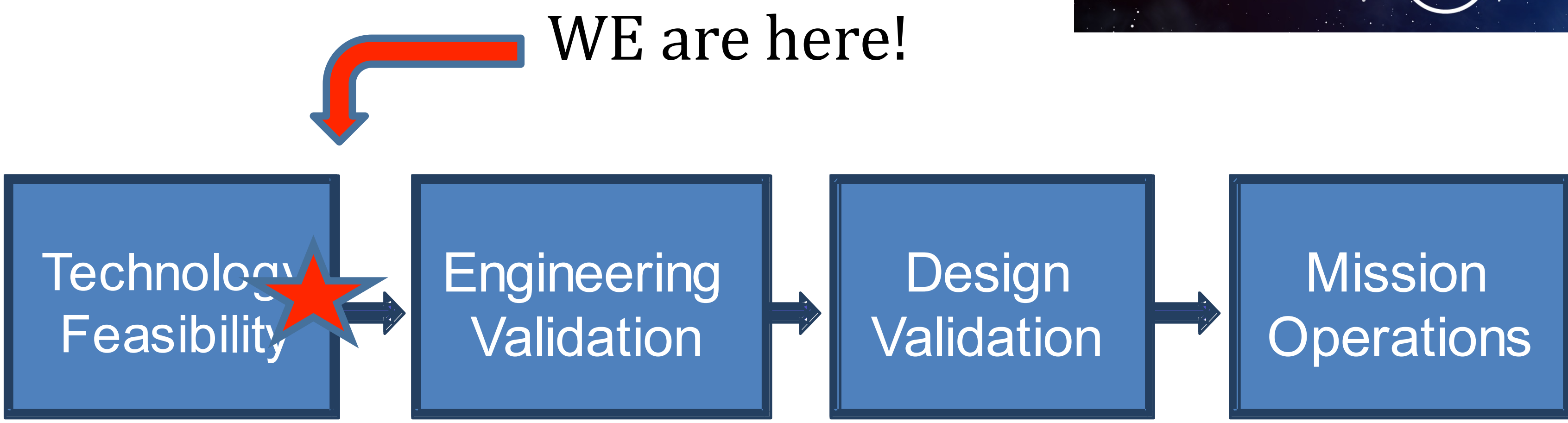
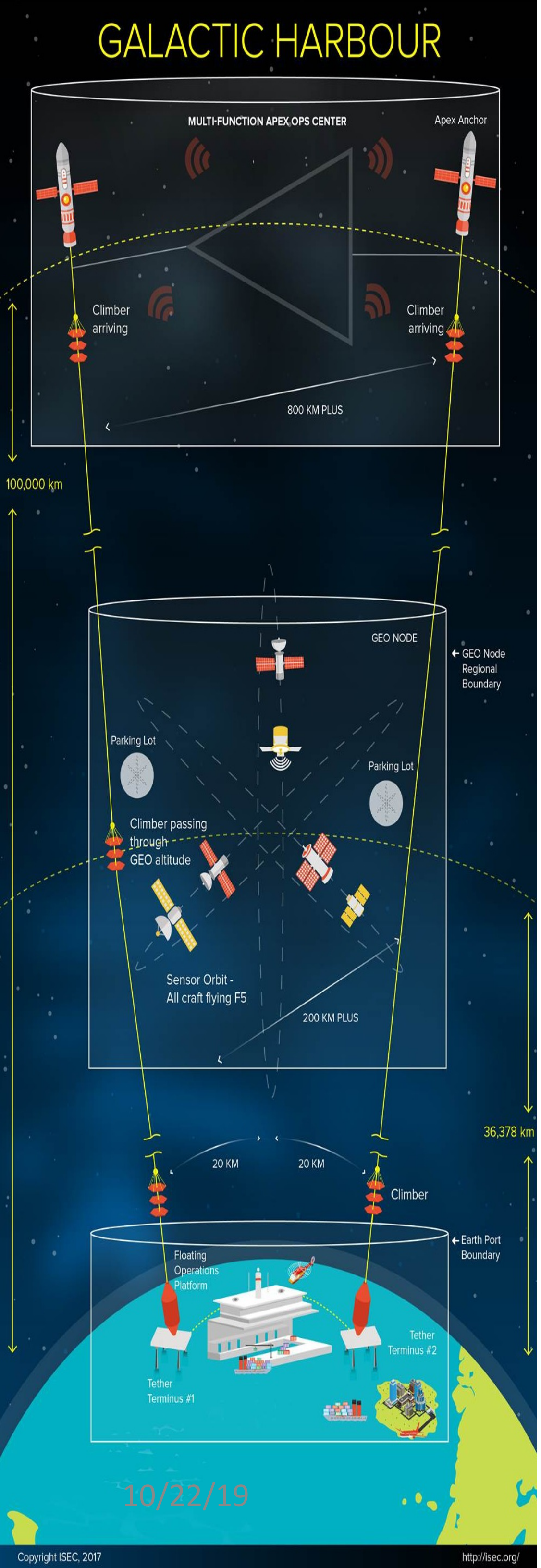
Engineering Development



- The technology development approach is to build around a set of well-defined demonstrations, inspections, tests and simulations to move the concept forward.
- The engineering teams around the Space Elevator development believe that we are very close to exiting the technology feasibility phase. This will require quite a bit of testing at the sub-system and system level for each of the major segments of the Space Elevator.
- This complexity is normal for all mega-project developments and is well understood.
- The rationale for exiting the first phase boils down to the readiness assessments as described for the phase one exit criteria, different for each mega-project.

Next Steps

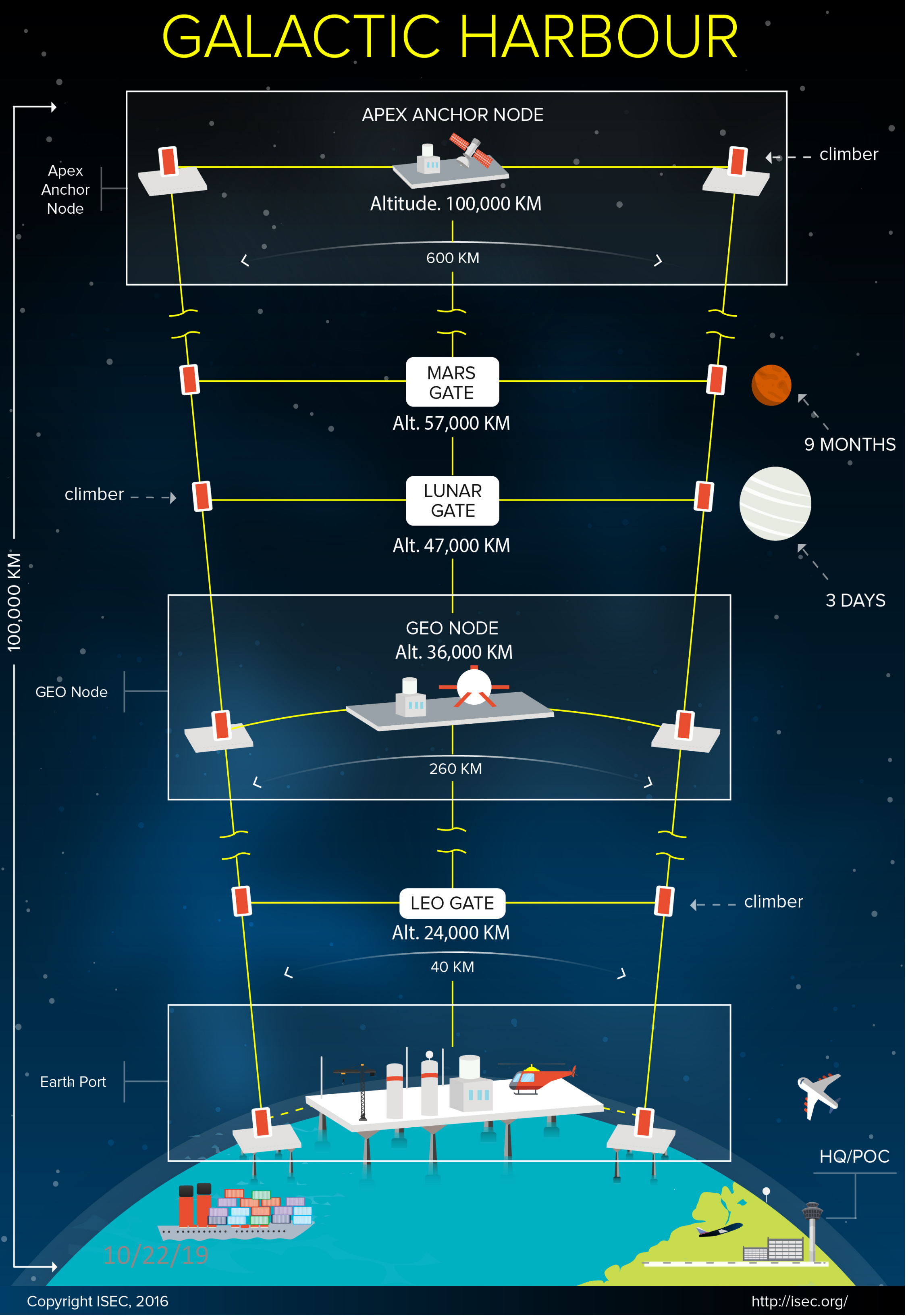
- The Space Elevator Community needs to be included in the discussions around access to space.
- The creation of a Space Elevator Institute will help the community address, and orchestrate responses to, critical questions, issues, and topics. This Institute would research major questions and ensure they are investigated leading to discussions within the larger space community, not just the Space Elevator community. There are two major thrusts that can be leveraged to start an institute:
  – Transportation Baseline Studies
  – Investigations into Chosen Topics



Conclusions

- The Materials are Ready for development
- We are ready to move into the second engineering development phase
- We are ready to join the discussions
- We need a Space Elevator Institute

Reliable, daily, routine, safe and environmentally friendly movement off-planet towards the Moon Mars and asteroids.

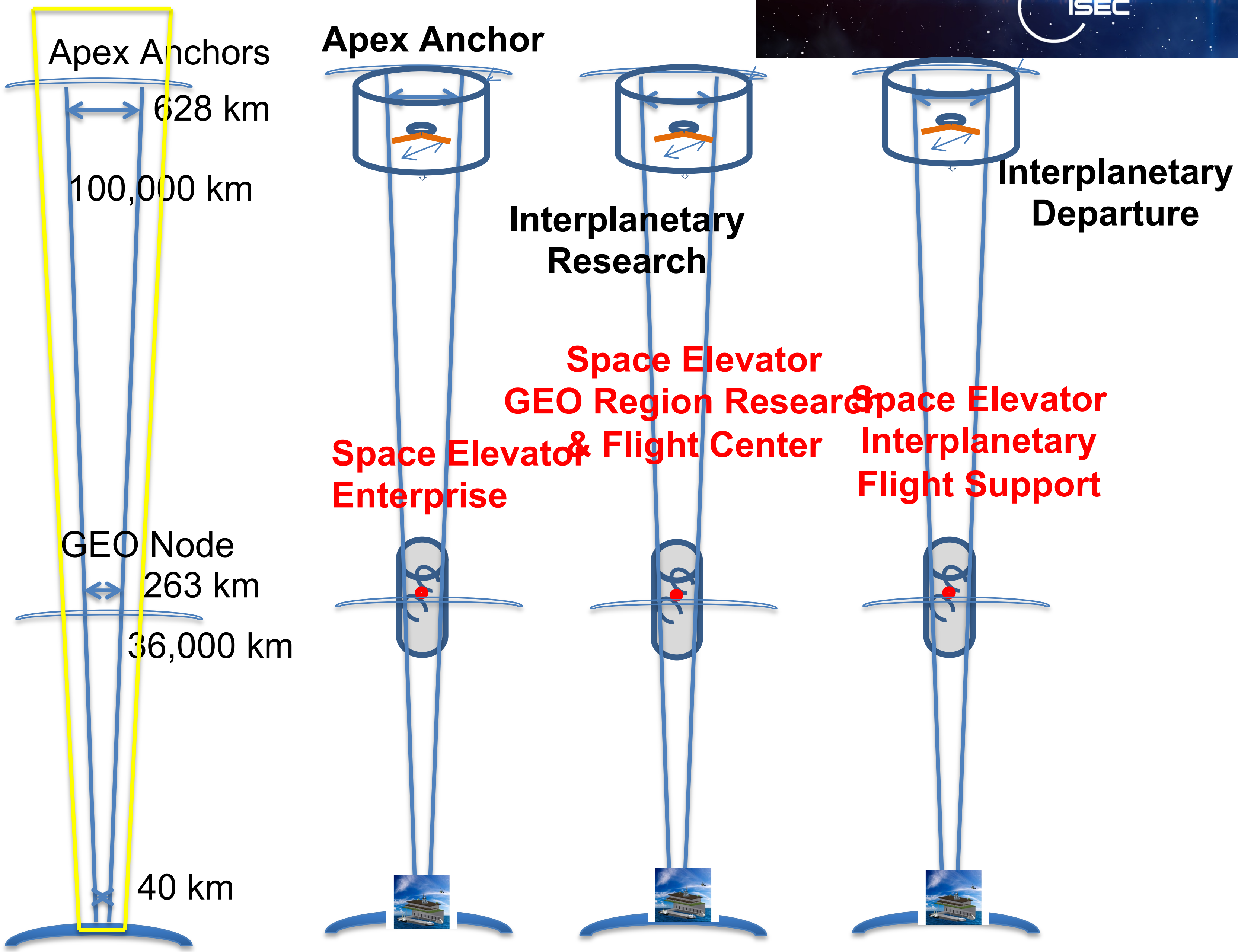


Our Vision of Space Elevators is a Galactic Harbour

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

… the Galactic Harbour.

Family Of Elevators



Recommendations

- *The vision of a Galactic Harbour should be enhanced as a unifying force for the space elevator community.*
- *Recognizing the strengths of space elevators leads one to realize that Movement off-planet will only happen when space elevators are supplying mission support within a cooperative arrangement with the future rocket infrastructure.*
- *Initiate a program soonest – while developing a Space Elevator Institute immediately.*

Final Thought

This could be the story of this century. Reliable, safe, and efficient access to space. This transportation capability is close at hand. Probably within 20 years. Space access without rockets! The Galactic Harbour opens the road, it opens the Heavens; it opens the way.

with the final realization:

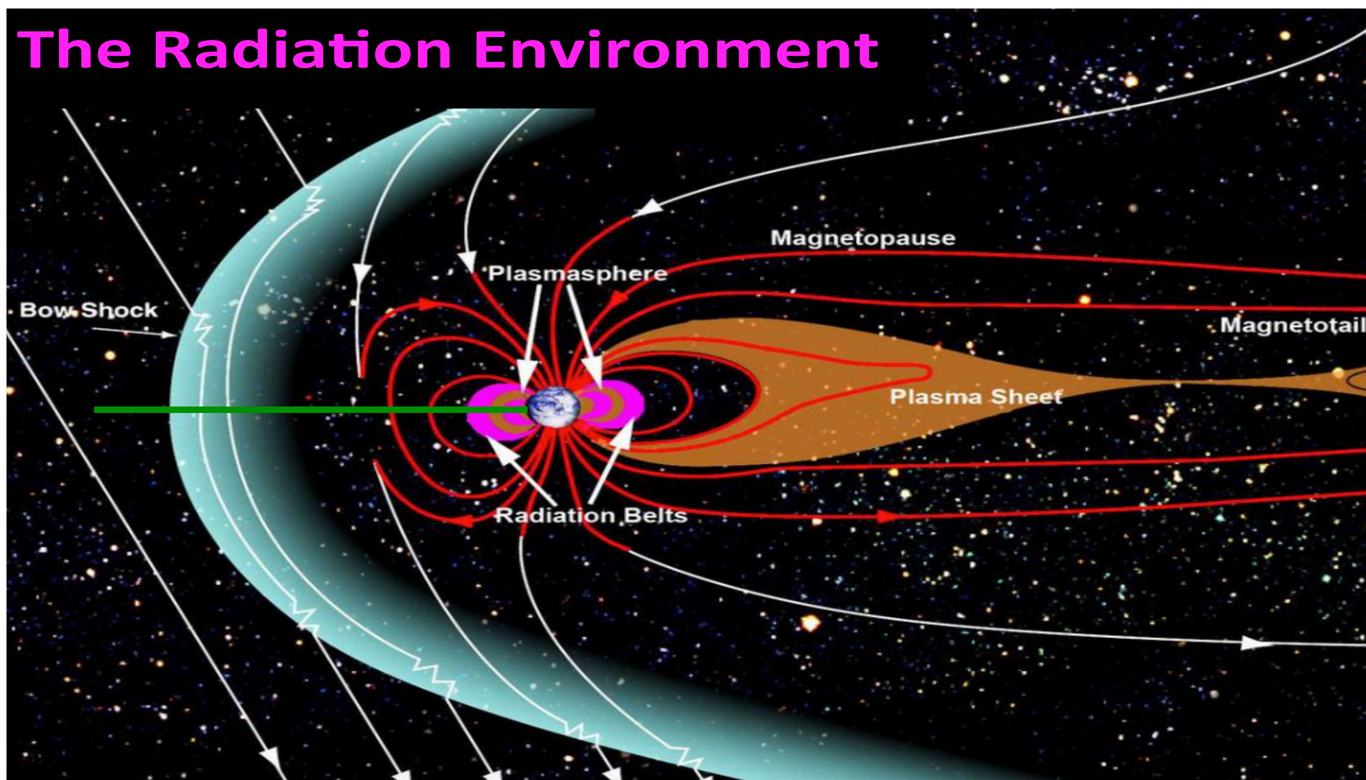
The Space Elevator is Closer than you Think!

How the Space Elevator Grew into a Galactic Harbour?

Backup Charts

Earth Radius
6,378 Km

Space Elevator
100,000 km
In green



Deployment Overview

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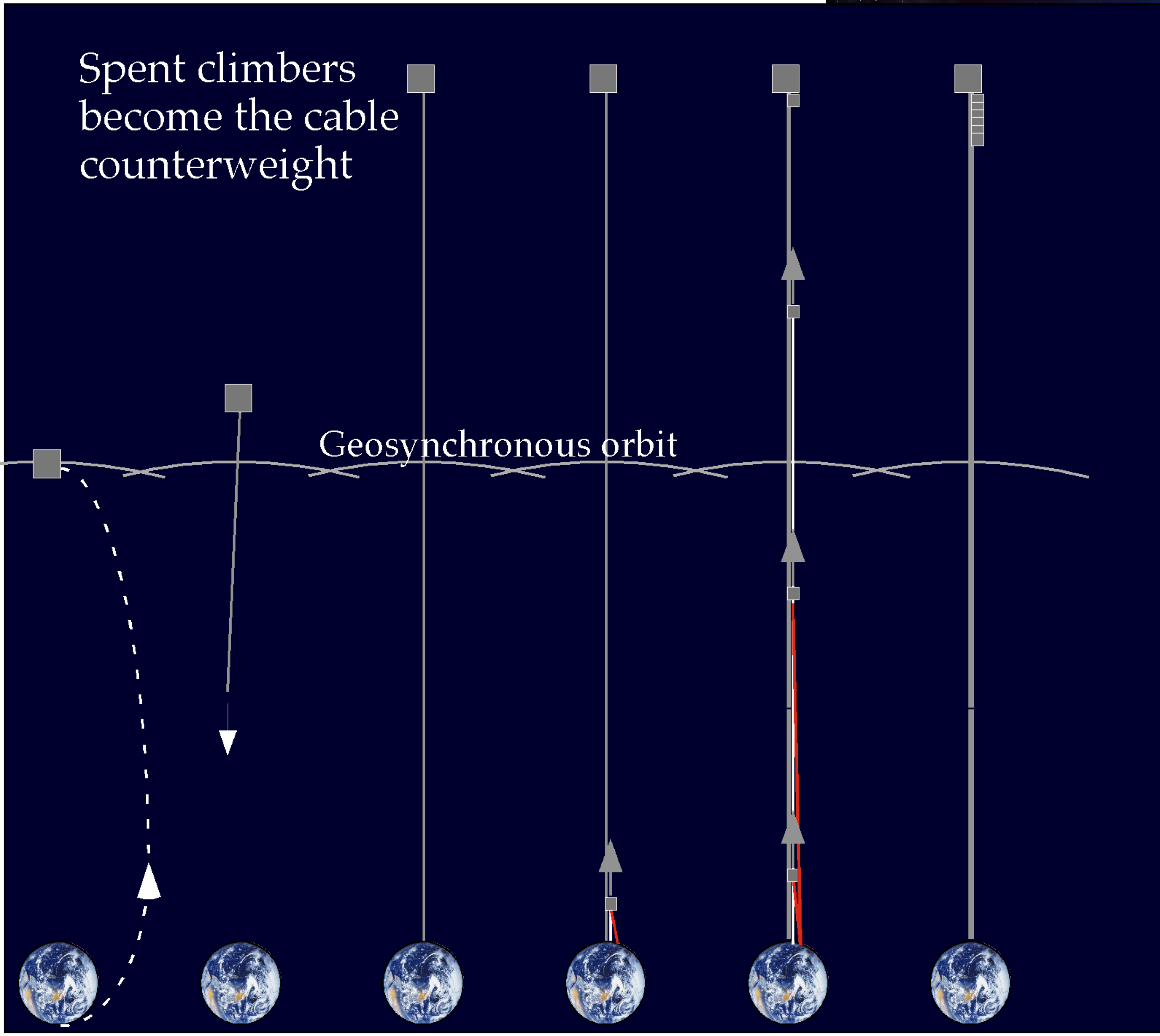

ISEC Study Activities

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Note: IAA - International Academy of Astronautics: ISEC - International Space Elevator Consortium

Notes: all completed studies on www.isec.org in pdf format for free **Study initiated August 2017 *Study being drafted

IAA Studies on Space Elevators

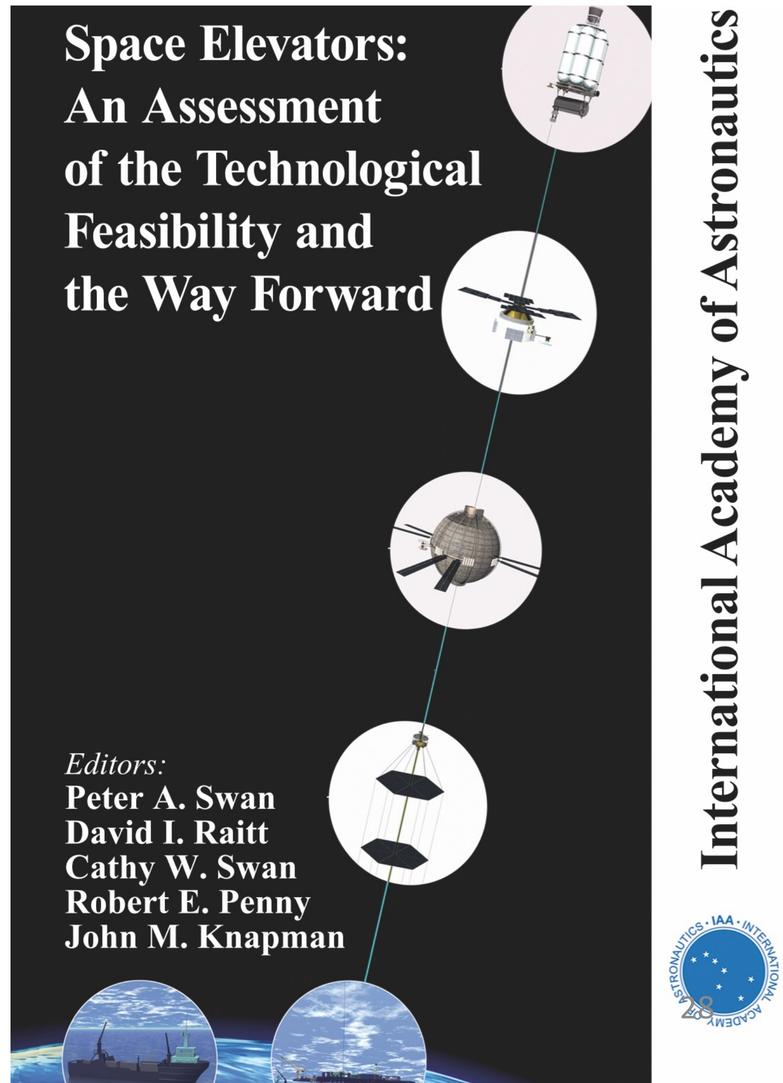
IAA Study One (2014) – Feasibility?

Conclusion: Space Elevators Seem Feasible

IAA Study Two (2019) How To? Maturity?:

Road to the Space Elevator Era

Many global experts evaluating critical technologies



Space Debris is a Manageable Challenge for Space Elevators

TOPICS to be Addressed:

Debris alert ➔ Warning needs

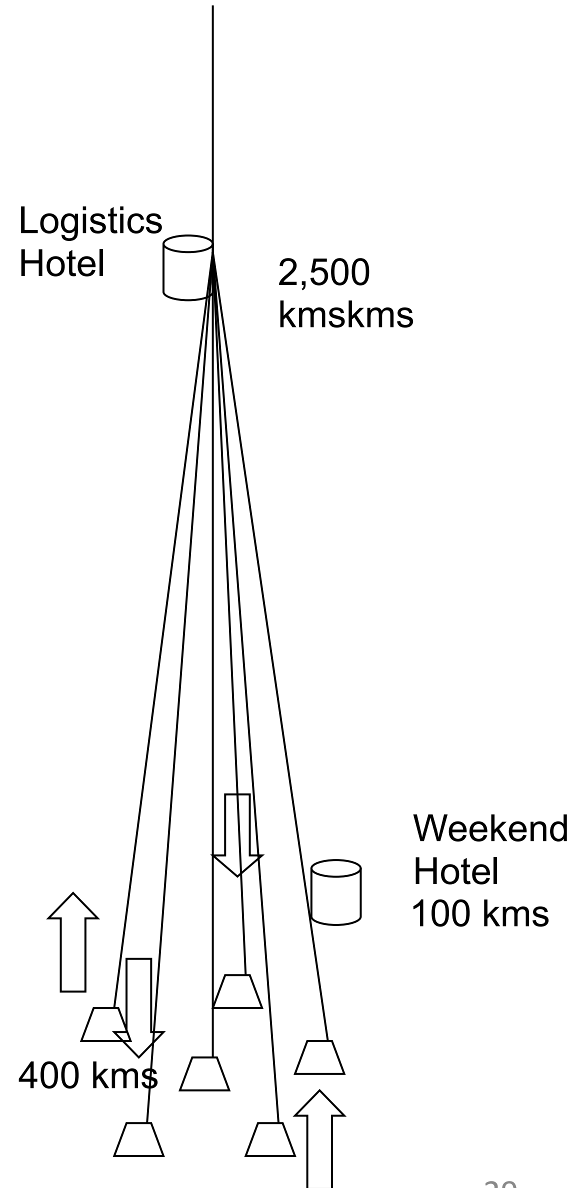
Debris sizing ➔ as a threat variant

Space Elevator Tether Movement ➔ passive defense

The Sentry System ➔ an Architecture adjunct for protection

System Recovery ➔ Post debris-event actions

Space Debris Adjunct (Mitigation) -- The Space Elevator will establish an op's relationship with space debris mitigation systems. The space debris "chair" will be charged with providing awareness, warning, active defense, passive defense, and (if needed) recovery after a debris event.

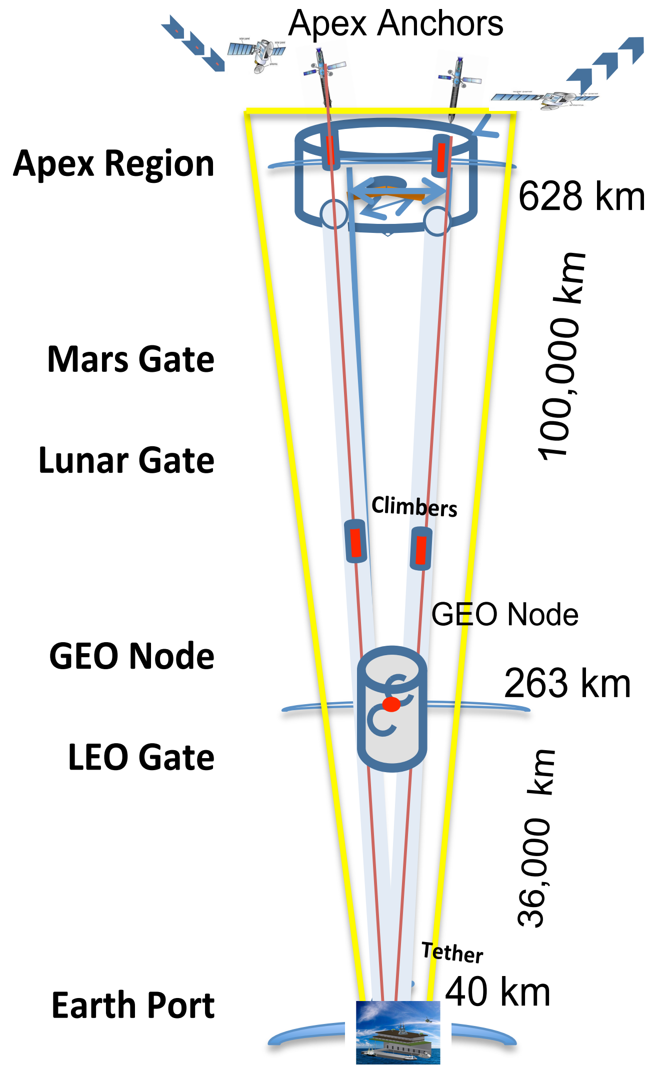


ISEC Approach

- Executive Summary of 2010 Report stated: To assess the risk to a space elevator, we have used methodology from the 2001 International Academy of Astronautics (IAA) Position Paper on Orbital Debris:
- "The probability (PC) that two items will collide in orbit is a function of the spatial density (SPD) of orbiting objects in a region, the average relative velocity (VR) between the objects in that region, the collision cross section (XC) of the scenario being considered, and the time (T) the object at risk is in the given region."

$$PC = 1 - e^{(-VR \times SPD \times XC \times T)}$$

- Using this formula, we calculate the Probability of Collision for LEO, MEO, and GEO. Our focus is on LEO -- as fully two thirds of the threatening objects are in the 200-2000 km (LEO) regime. Our analyses show:
- 2001 Position Paper On Orbital Debris, International Academy of Astronautics, supported by NASA, 24.11.2000. download for free from www.isec.org



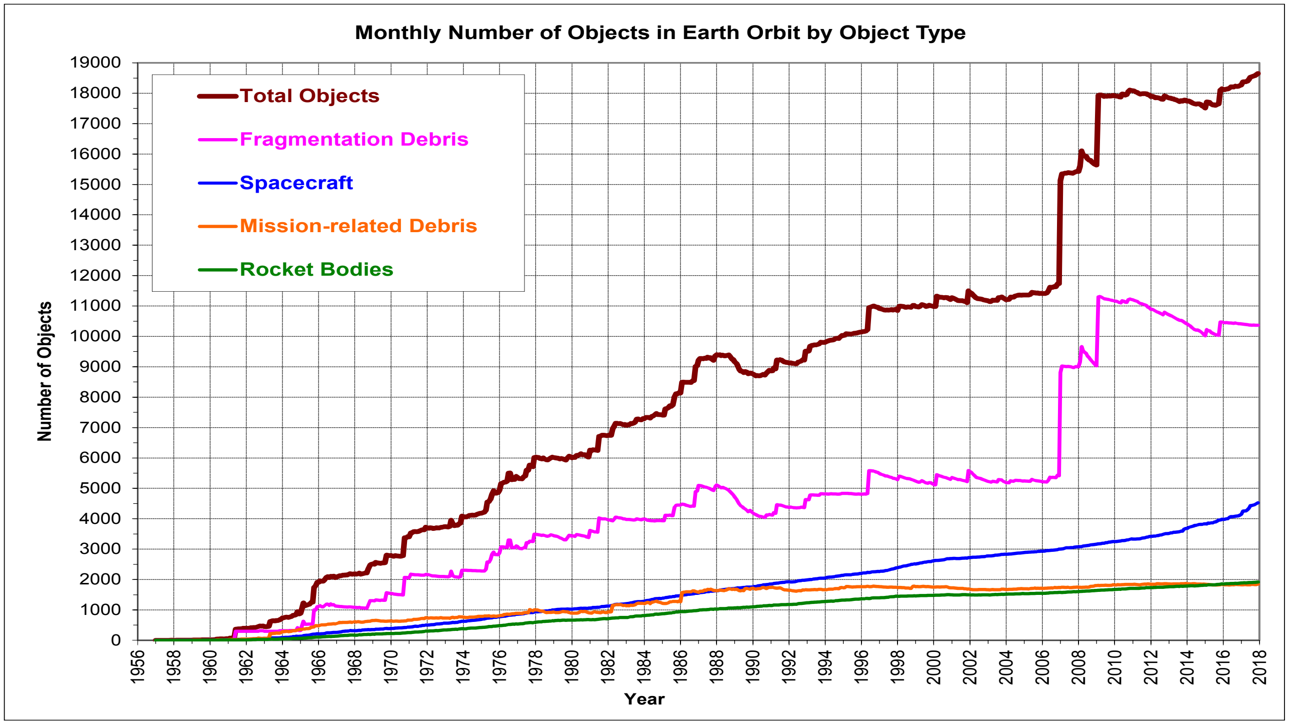
Summary for Future

Item	*2010*	*2019*	*2030 Est.*	*Comment*
Total Tracked Debris by NASA	15378	19137	38,000	Assume comm constellations will add many space objects
Threats in GEO region	Not significant	Not significant	Not significant	Good operational proceedures a must.
Threat in MEO region	Not Significant	Not Significant	Not Significant	Good operational proceedures a must.
Untracked, small (<10 cm) debris will impact a Space Elevator in (LEO 200-2000 km), on the average;	Once every ten days	Once every 7.5 days	Once every 4 days	Design for tether anc movement planned to account for this - with continuous repair
Tracked debris will impact the total LEO segment (200 – 2000 km) if no actions are taken.	Once every 100 days or multiple times a year	Once every 75 days or several times a year	Once every 40 days or every two months or so	Note, this assumes there is no active movement of trackec objects or of the tether
Tracked debris will only impact a single 60 km stretch of LEO space elevator, on the average	Every 18 years with every 5 years in peak regions	Every 14 years with every 4 years in peak regions	Every 7 years with every 3 years in peok regions	Note, this assumes there is no active movement of trackec objects or of the tether

Conclusion

- As a result, the conclusion stays the same: - for 2009, 2018 and 2030
- Space debris mitigation is an engineering problem with definable quantities such as density of debris and lengths/widths of targets. With proper knowledge and good operational procedures, the threat of space debris is not a show-stopper by any means. However, mitigation approaches must be accepted and implemented robustly to ensure that engineering problems do not become a catastrophic failure event.
- And there are always the engineering solutions for some of the challenges. Many people have suggested architectural designs to help the issue. Here are some of them:
- Eliminate the major debris in orbit (this is a must - and there are many people around the world who believe this must be started soon to ensure no future challenges to normal spaceflight - this is NOT a space elevator issue alone, but one for all spaceflight.)
- design an emergency response that sends tether from GEO downward when the tension jump signals a major change resulting from sever.
- provide an emergency lowering of tether from 2,000 km upon sever in the highest probability areas (LEO high density orbits)
- provide multiple legs from 2,000 kms and below. [I actually like that one - see image below]

Space Debris Sept 2018



Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris" includes all objects dispensed, separated, or released as part of the planned mission.

Item	*2010*	*2019*	*2030 Est.*	*Comment*
Total Tracked Debris by NASA	15378	19137	38,000	

Orbital Debris Quarterly News

Sep 2018 Orbital Debris Quarterly News(NASA Johnson Center office)

SATELLITE BOX SCORE

(as of 04 July 2018, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

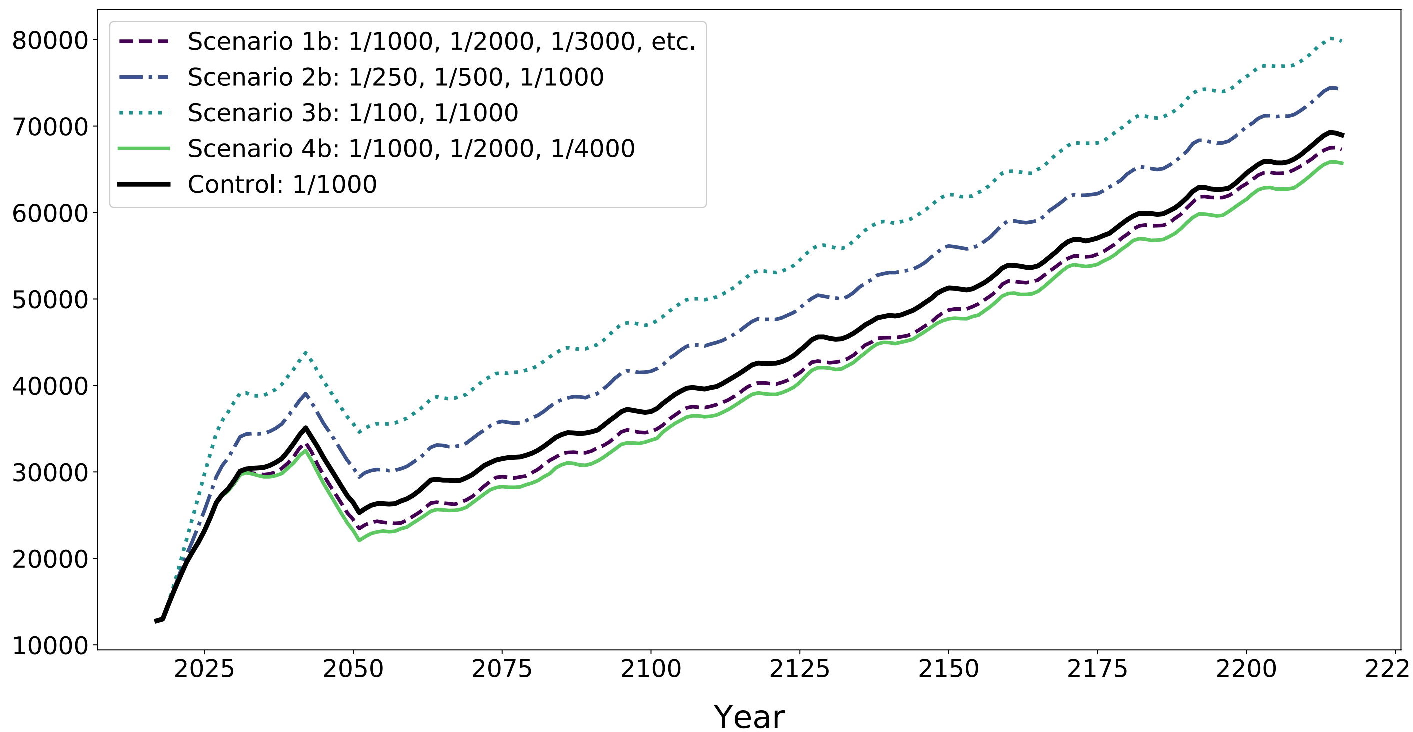
Country/ Organization	Payloads*	Rocket Bodies & Debris	Total
CHINA	312	3652	3964
CIS	1520	5069	6589
ESA	82	57	139
FRANCE	64	488	552
INDIA	89	117	206
JAPAN	173	111	284
USA	1663	4737	6400
OTHER	887	116	1003
TOTAL	4790	14347	19137

* active and defunct

Effects of Large Constellations - NASA

"Therefore, constellation operators should design spacecraft to ensure an accidental probability of explosion of 1/1000 or better from the initial constellation deployment in order to protect the future space environment."

An Extended Parametric Study of the Effects of Large Constellations on the Future Debris Environment
Oribital Debris Quarterly News, Vol 23, I 3, Aug 2019, pg 5-8



re 2. Effective number of objects projected to be in orbit after 200 years with varying explosion rates over each replenishment cy
bulge represents the constellations deploying and the subsequent fall-off represents the end of the constellations lifetime, i.e., ti
o additional constellations being added to the environment.