Beneficial Environmental Impacts of Space Elevators

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ISEC Study Activities

Table 1, Study Summaries, ISEC

Year	*Title of ISEC Yearly Study Reports (www.isec.org/studies)*
2021	Design Considerations for the Space Elevator Climber-Tether Interface - just starting
2021	Beneficial Environmental Impacts of the Space Elevator - in work
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

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

Case for Dual Space Access Architecture

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

Space Elevator Strengths: As permanent infrastructures they lead to daily, routine, environmentally friendly, and inexpensive departures toward mission destinations. In addition, their Interplanetary mission strengths are: Departs daily from Apex to Mars (no 26-months wait between launch windows) with rapid transit (61 days best time) and massive support (170,000 tonnes per year).

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.

Dual Space Access Architecture

Future Space Delivery Customer Demands:

- One Million Tonnes to Mars - Request by Elon Musk for his Colony support*
- Five Million tonnes to GEO – Request by Dr. John Mankins for Operational Space Based Solar Power**

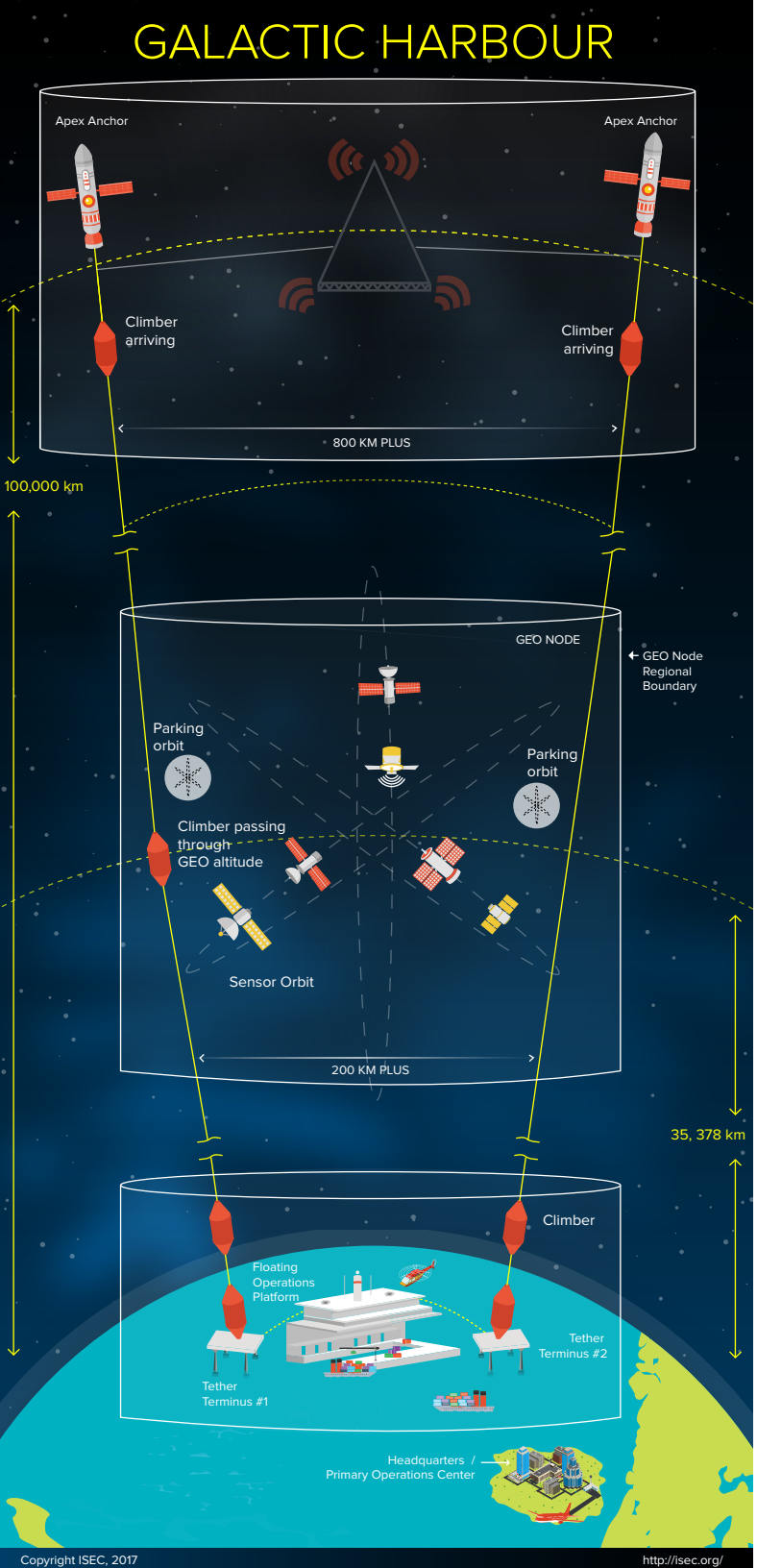
Projected Breakout:
Rockets to Open up the Moon and Mars with Space Elevators to supply and grow the colonies.

*Elon Musk, 21 July 2019, CBS Sunday Morning Interview
**Mankins, John, conversation with P. Swan
at IAC Washington DC Oct 2019.

Big Green Machine

- Future Logistics Needs; With the current efforts to put boots on the Moon and Mars in the next fifteen years, there will be tremendous needs for logistics support, movement of manufactured goods as well as transporting people [especially at low cost and routine/daily].

- The net assessment trade study: ISEC has shown that Space Elevators and Galactic Harbours are “Big Green Machines” designed to improve the Earth's environment through two significant contributions: (1) A remarkable "zero-emission" lift of cargo to space - reducing environmental impacts from only rocket launches. (2) The ability to deploy massive systems that can improve the Earth's environment (SBPS and Solar Shield).

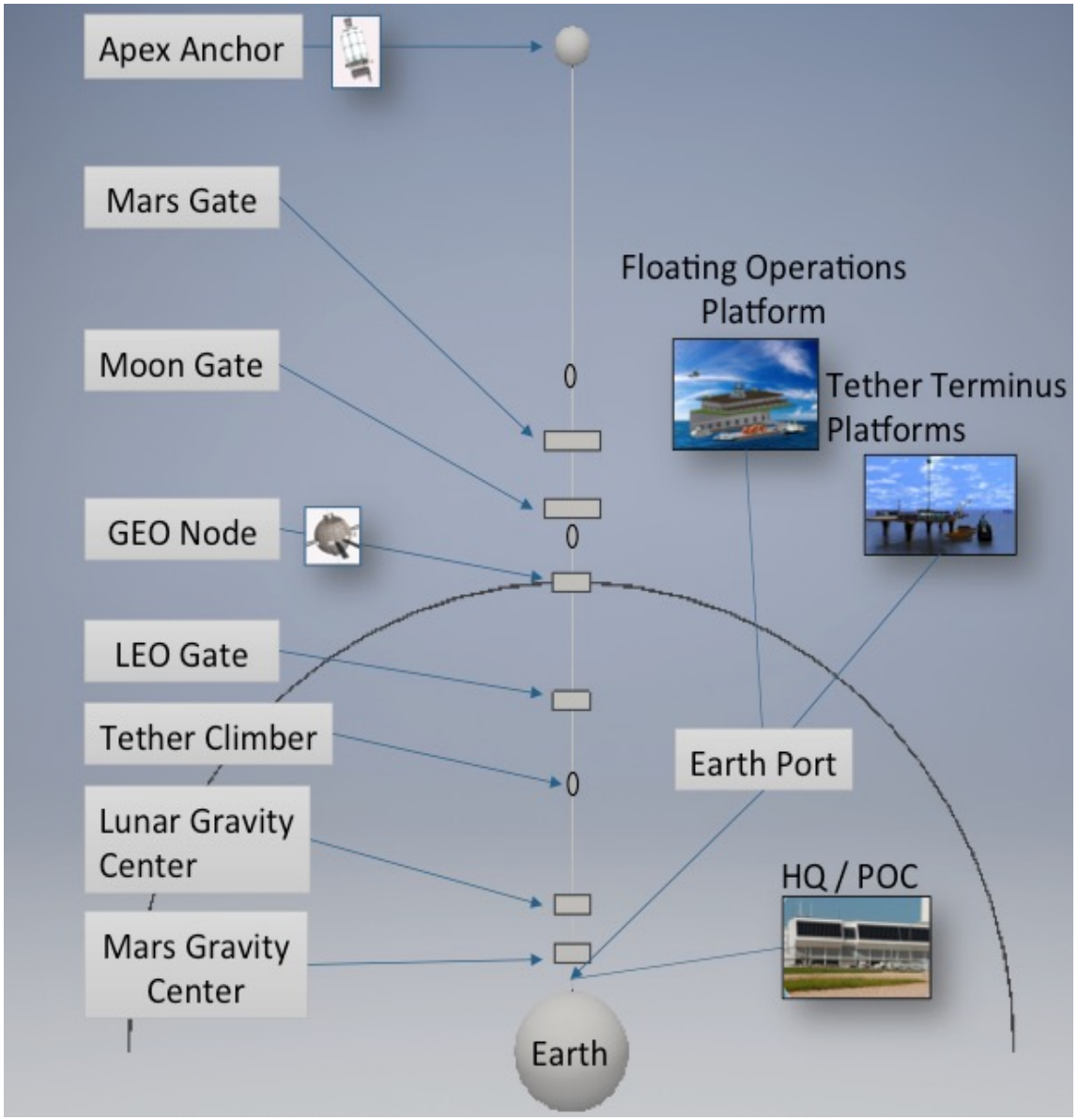


Today's Agenda

- Introduction
- Enabling Green Technologies
- Comparison of Environmental Impacts – Future Rockets and Space Elevators
- Conclusion

Space Elevators Enable Access to space with environmentally friendly liftoffs.

Lexicon for a Space Elevator

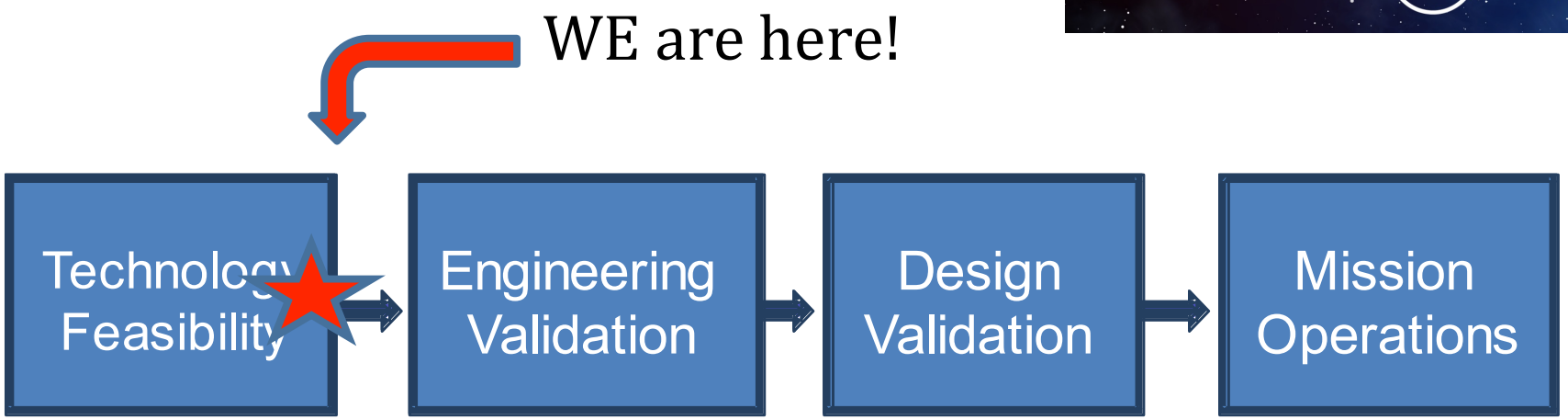


Apex Anchor Node
Mars Gate
Moon Gate
GEO Node
LEO Gate
Lunar Gravity Center
Mars Gravity Center
Tether Climbers
Tether Structure
Earth Port
- Earth Terminus
- Floating Operations Platform

Headquarters and Primary Operations Center (HQ&POC)

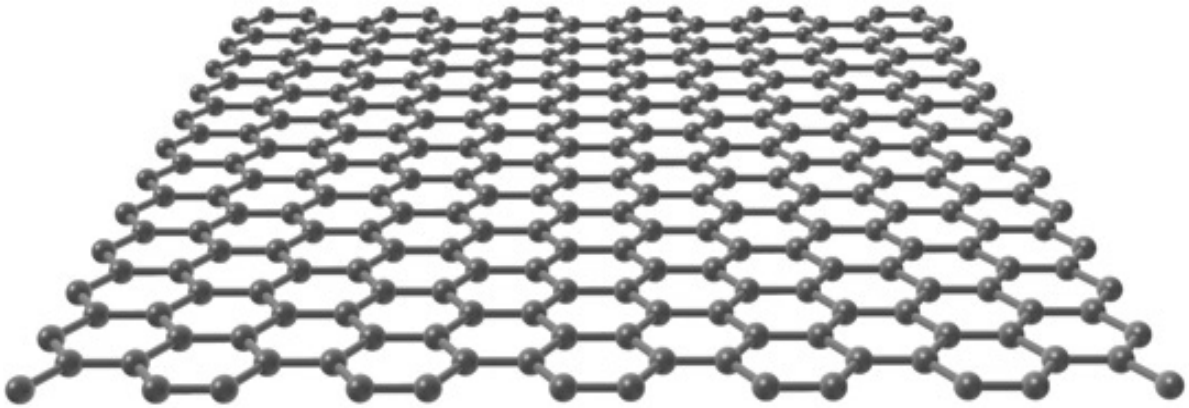
Major centers of activity
Locations on tether
Tether Material in development

Engineering Development

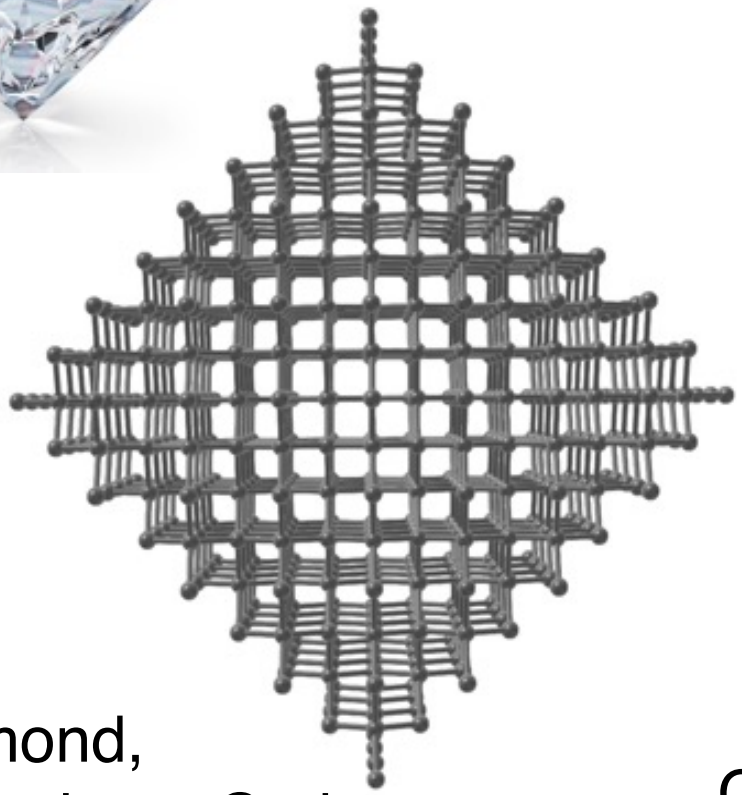


- The technology development approach is to build around a set of well-defined demonstrations, inspections, tests and simulations to move the concept forward.
- The engineering teams around the Space Elevator development believe that we are very close to exiting the technology feasibility phase. This 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, which is different for each mega-project.

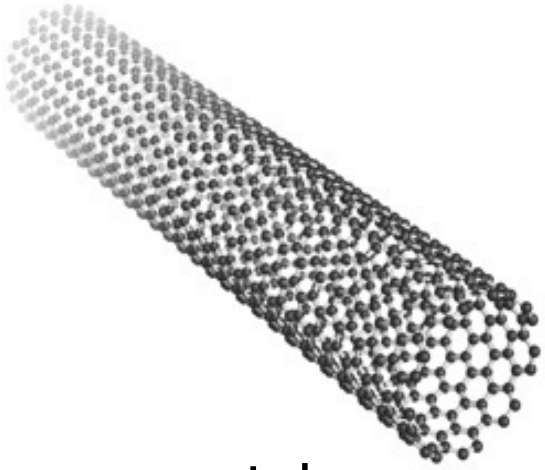
The carbon family



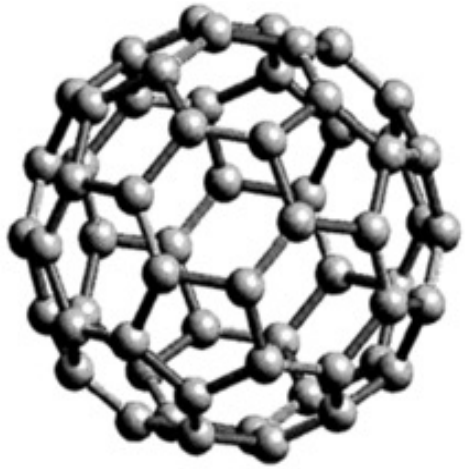
Graphene:
2D material



Diamond,
Amorphous Carbon:
3D material



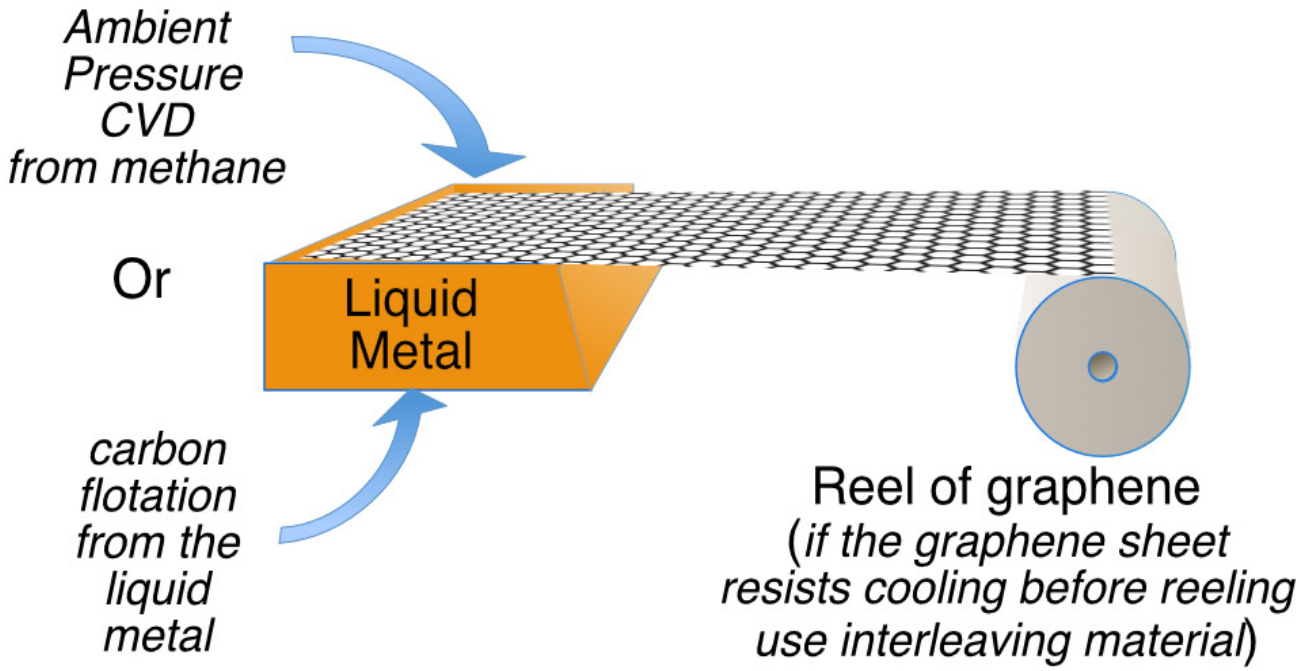
Carbon nanotubes:
1D material



Fullerenes:
0D material

Graphene: A new continuous process

Principles for making continuous single crystal sheet graphene



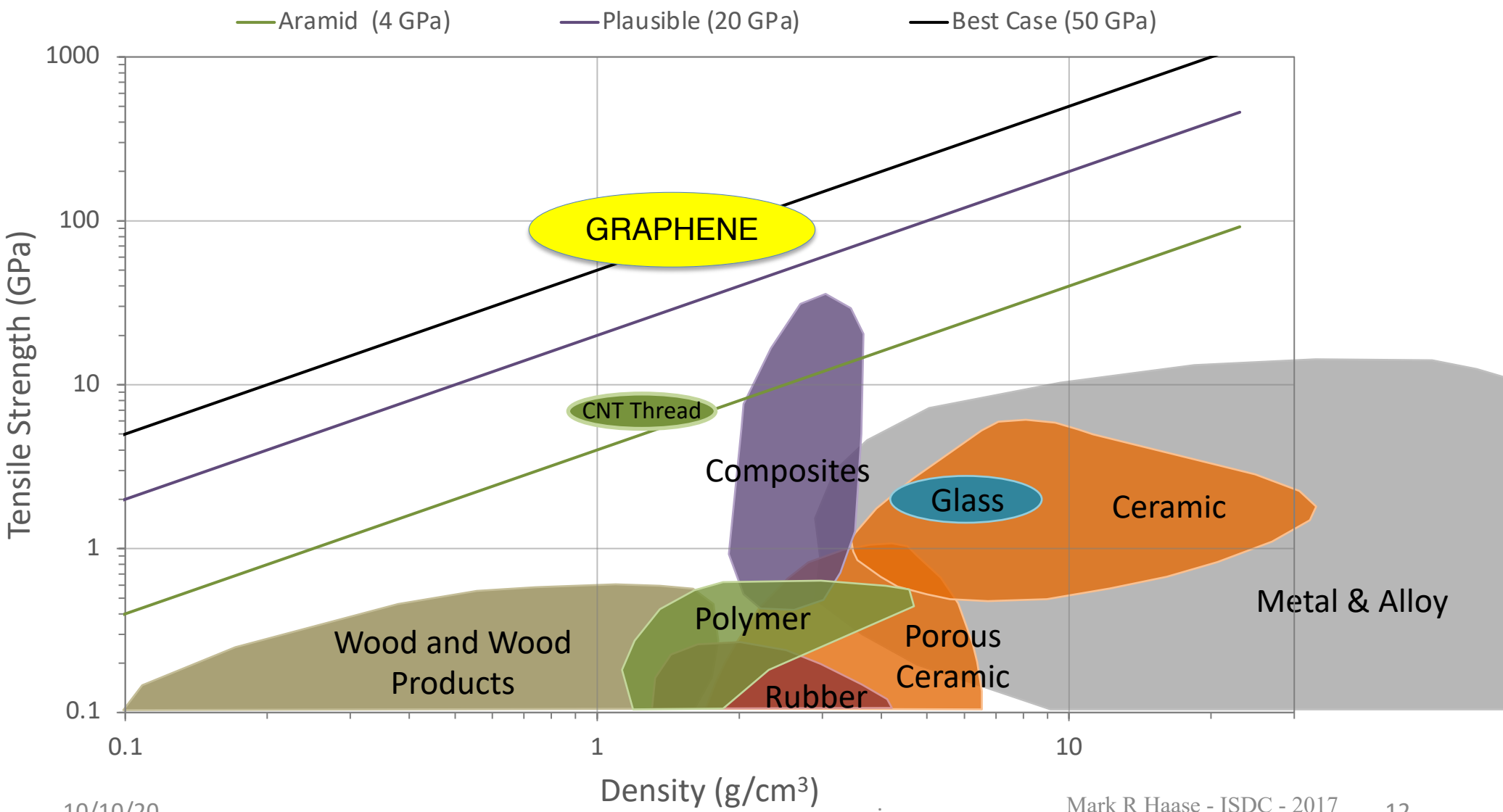
Hypothesis published to test it amongst the world's top graphene scientists. (While retaining key intellectual property)

This hypothesis has not been invalidated to date.

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

Tether candidate materials

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



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.

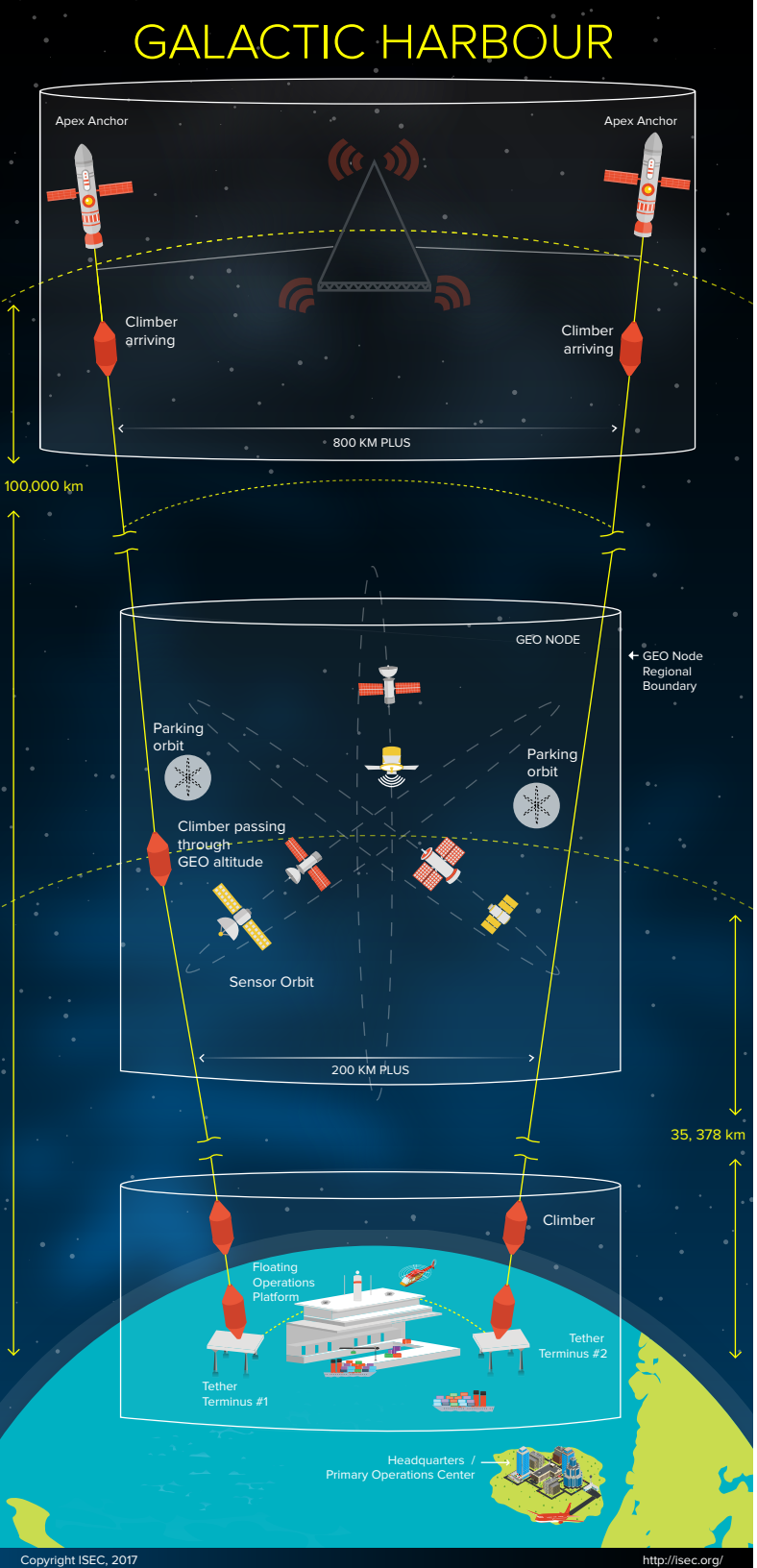
Layered single crystal graphene is yet to be made but we know how to do this and the material is already being called Nixene

YES

Graphene tether material really is possible within our lifetimes.

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 [available 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
- Special strengths for Interplanetary
  - Massive loads per day [starts at 14 tonnes cargo loads – grows to 79]
  - 61 days fast transit (transit time vary over the 26 month planetary dance)
  - Release towards Mars every day



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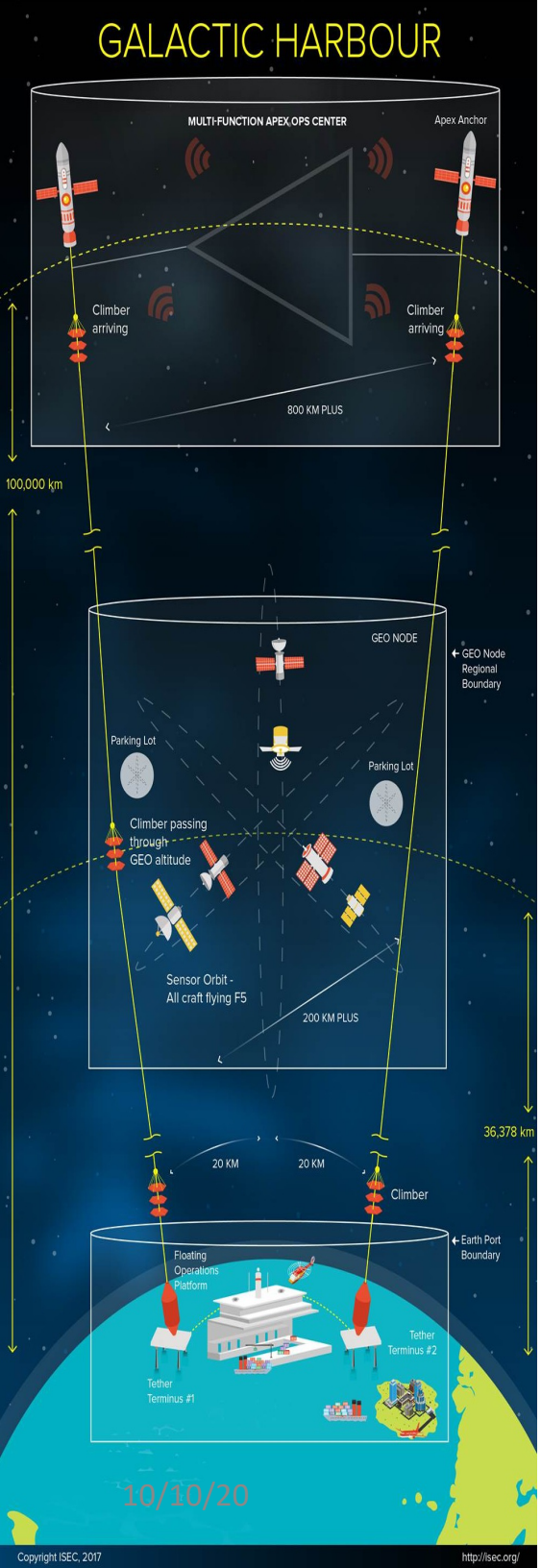


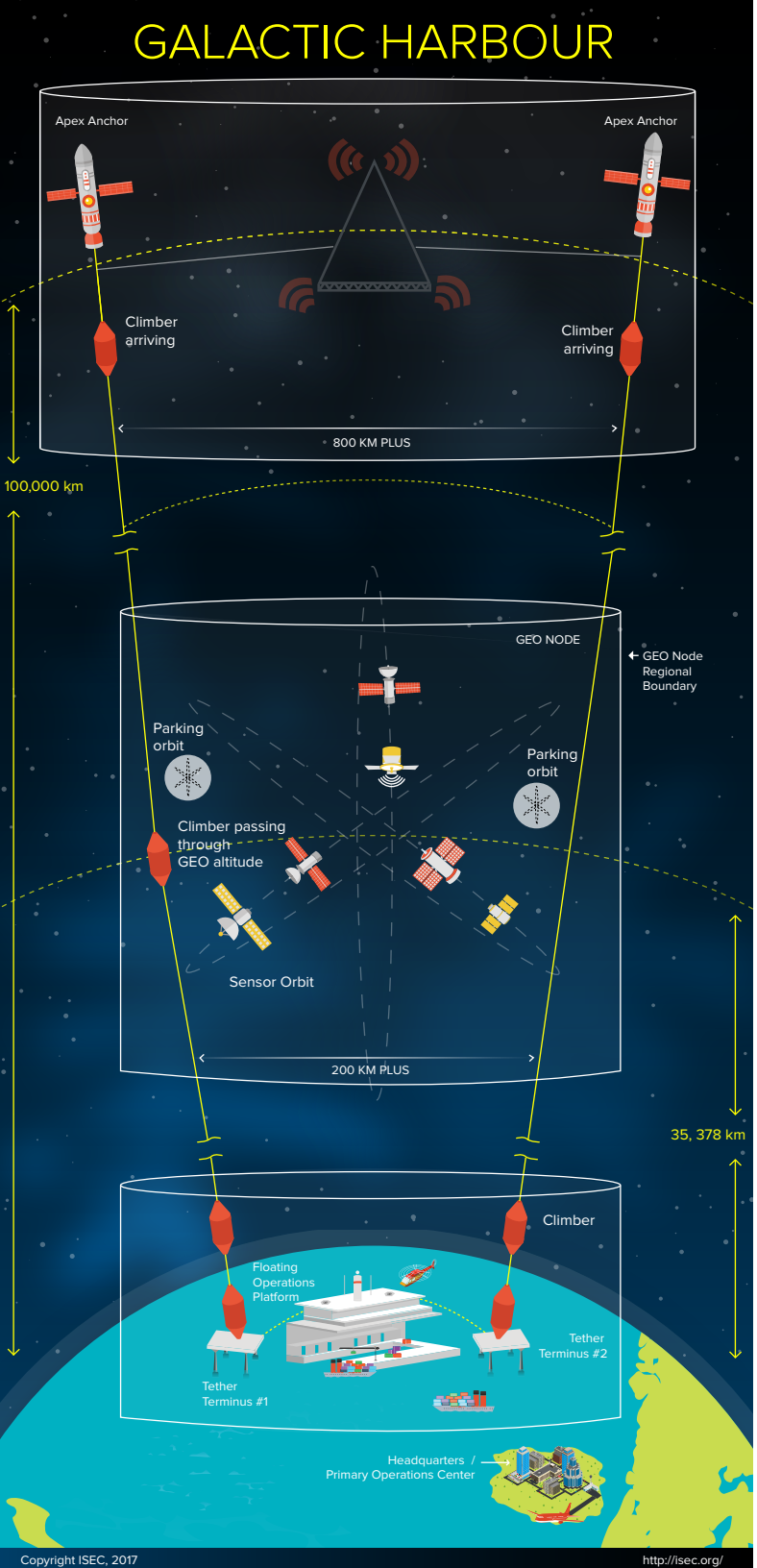
Big Green Machine Space Elevators

- Inherently Environmentally Friendly: Space Elevators are carbon negative in both construction and then operations. Raising to orbit using solar power energy negates any consumption and burning of fuels in the atmosphere.
- Teams with Rockets for zero Emission lift-offs: Carbon negative Space Elevators will contribute to the betterment of the Earth's atmosphere with missions enabled, as the reduction of rocket launches is effected.
- Enables Earth Friendly Missions: The following list shows positive effects to “green” the Earth: Space Based Solar Power, Nuclear Waste disposed towards Sun, Manufacture of graphene tethers will remove CO2 from the atmosphere (6,300 tonnes per space elevator x 6 or 37,800 tonnes in stable solid Carbon atomic state), future missions such as recycle and repair old satellites, and practical logistical support for Mars or Moon colonies without using rockets to escape from Earth's gravity well

Enabling Green

- The question on the table is: how can the strengths of Space Elevators enable missions of all types, while having minimal or no environmental effect on our planet? We believe that not only can Space Elevators do this but also allows activities in space that will improve Earth's environment.
- Space Based Solar Power: John Mankins* stated: "an extensive SBSP program can stop global warming and possibly reverse it." He has also stated that he needs 5 million tonnes to GEO to provide electrical power to 12% of Global population by 2060.**
- High Level Nuclear Waste: The current approach for H-L NW disposal is still not satisfactory; especially, as Space Elevators could lead to a concept of safe disposal, permanently with small risk.
- Repair and refuel at GEO: inexpensive and environmentally negative lifts to GEO will enable robust businesses to develop.

*Mankins, John webinar entitled " NSS Space Forum on 20 August - A Case for Space-Based Solar, Power
**Mankins, John, conversation with P. Swan at IAC Washington DC Oct 2019



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Comparison – Rockets vs. Space Elevators

- When embarking on a long journey, each of us thinks about the destination first. However, to have a successful journey, one must also consider the other factors:
  - cost, travel time, environmental impact, availability, value delivered, safe and resource efficiency.
- Conclusion: When Space Elevators are ready, the factors influencing movement of mission payloads will not be dominated by resource consumption and environmental impact.
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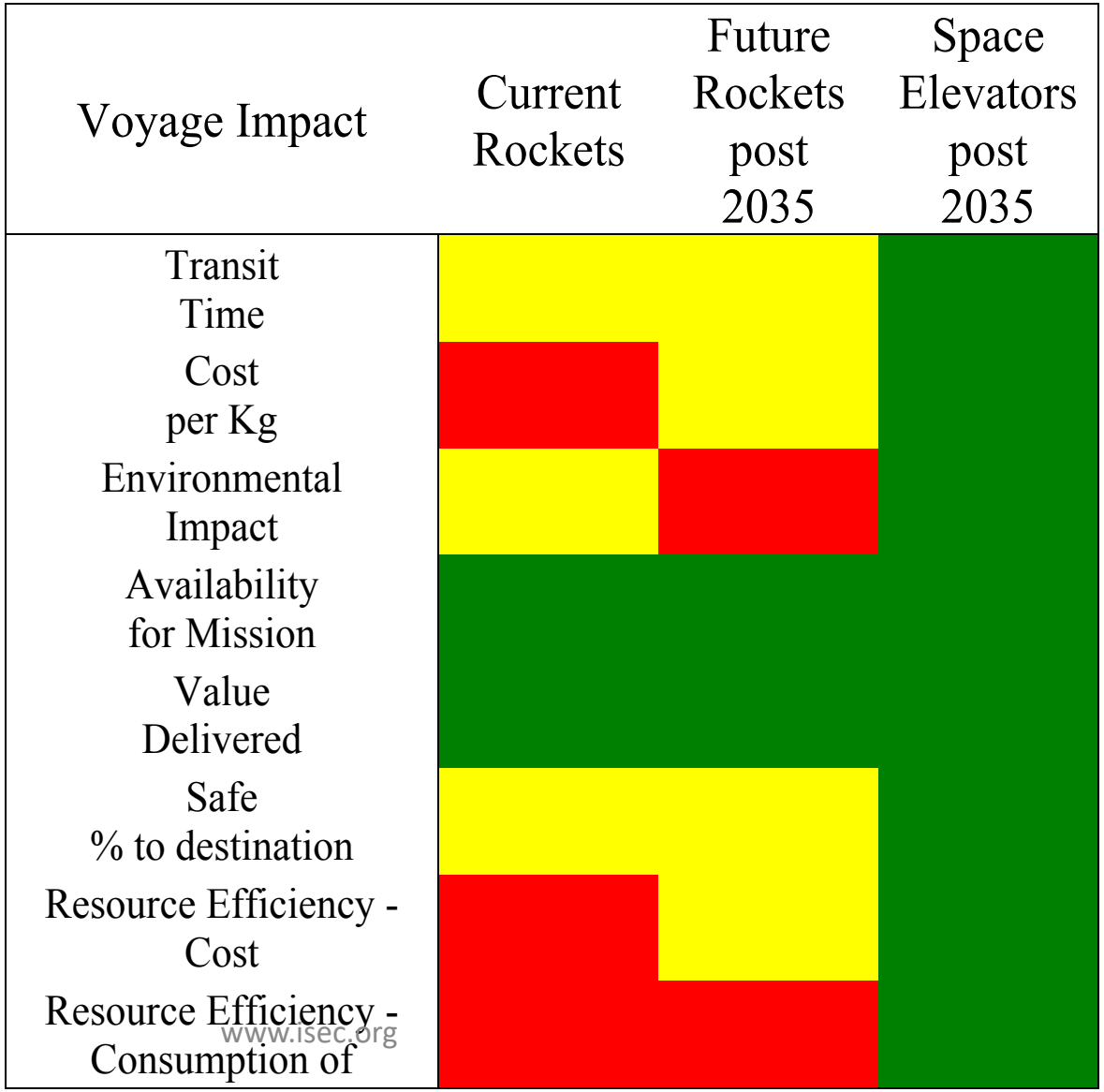
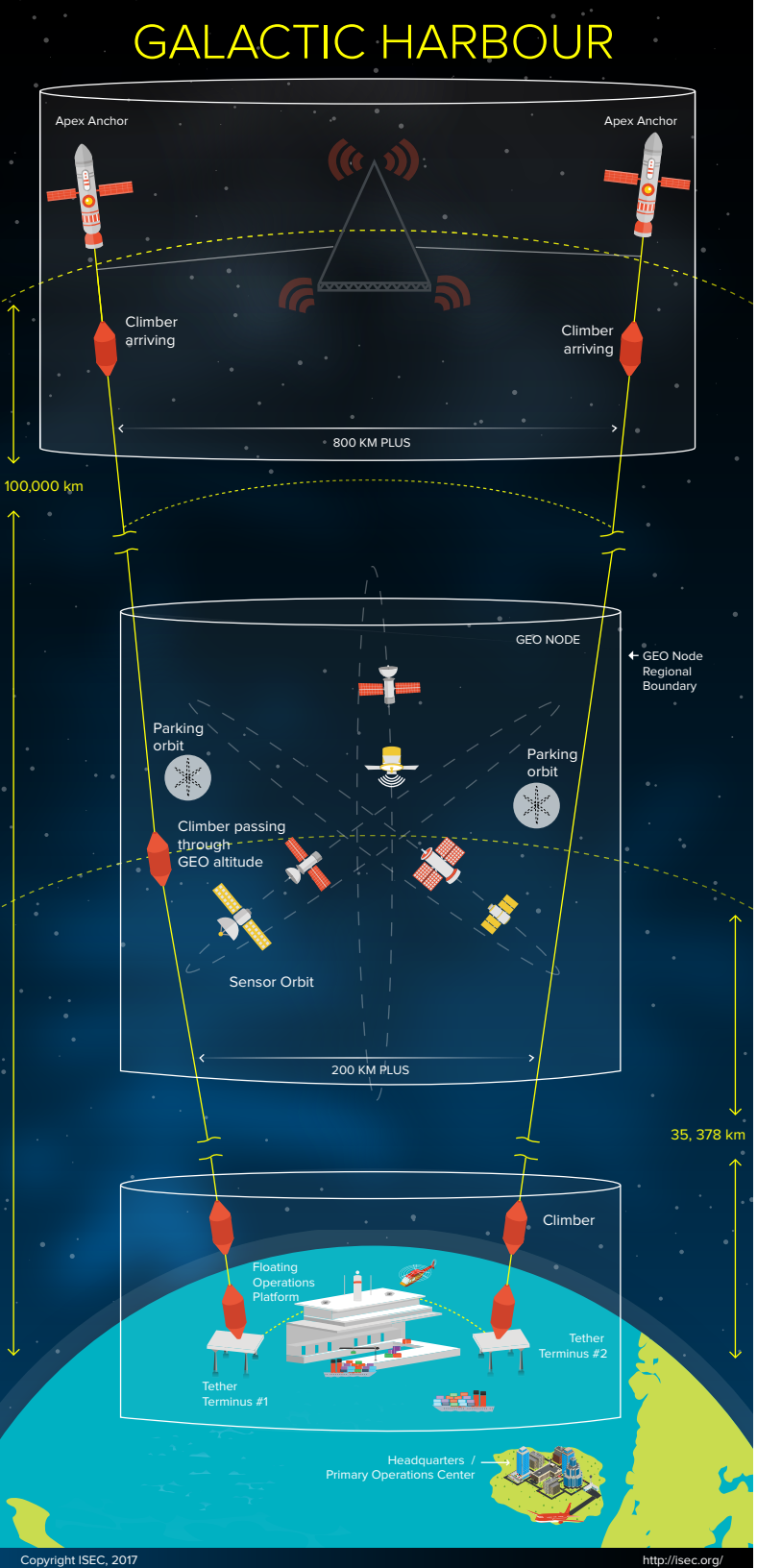


Impact of the Rocket Equation

- The problem: "a device that can apply acceleration to itself using thrust by expelling part of its mass with high velocity can thereby move due to the conservation of momentum." The Tsiolkovsky rocket equation still responds to that critical factor called gravity. The Earth's gravity numbers have a consistent impact on effectiveness at liftoff and flight - DRACONIAN!
- Goddard and Von Braun recognized this monumental problem and found ways to "work through it." The gravity well is very deep, resulting in:
  - Average – 4% of launch pad mass to LEO & 2% to GEO/TLI
  - Apollo – 0.5 % landed on surface of Moon, 0.2% returned to Earth
- Note: Cost nor re-usability effect Rocket Equation. Mass is consumed to beat the Gravity Well. Mr. Musk has better efficiency and cost – but not mass to orbit.
- Example: to establish 5 million tons to GEO for SBSP, would require approximately 250 million tons on the launch pad.



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Realization

- The Dual Space Access Architecture combining rockets and space elevator strengths result in tremendous advantages in the "greening of the Earth."
- The first advantage from leveraging rockets is the rapid transit through the radiation belts with people occurring as often as requested as they are not being used for logistics.
- The second advantage with Space Elevators is that all the robotic movement of mass (cargo, habitats, air, water, etc) would be done safely, routinely, daily, environmentally safely, and inexpensively by Space Elevators.

Dual Space Access

This separation of delivery approaches will greatly enhance the missions of the future. When the customer demands matures to support near term missions such as Space Based Solar Power (5 million tonnes to GEO) and a Mars Colony (1 million tonnes to Mars), the value of Space Elevators will become obvious. When the Space Elevator delivers 80% of the mass needed for a critical mission, the savings in cost, time and environmental impact will make us ask "Why not earlier?"