Architecture Engineering and the Galactic Harbour

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EVP & Co-Founder - Galactic Harbour Associates, Inc.

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14:00 Coordinated Universal Time (UTC)

Michael Fitzgerald – "*Fitzer*"

ISEC Board member
Chief Architect

The International Space Elevator Consortium

USAF Academy 1968
University of Southern California 1978

Over 50 years experience in space projects;

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What we will cover…

- Galactic Harbour
- Space Elevator segments
- Architecture Engineering
- Technology Maturity
- Transportation Elixir
- Interplanetary Transportation Network

The Galactic Harbour

Los Angeles and Long Beach Harbor

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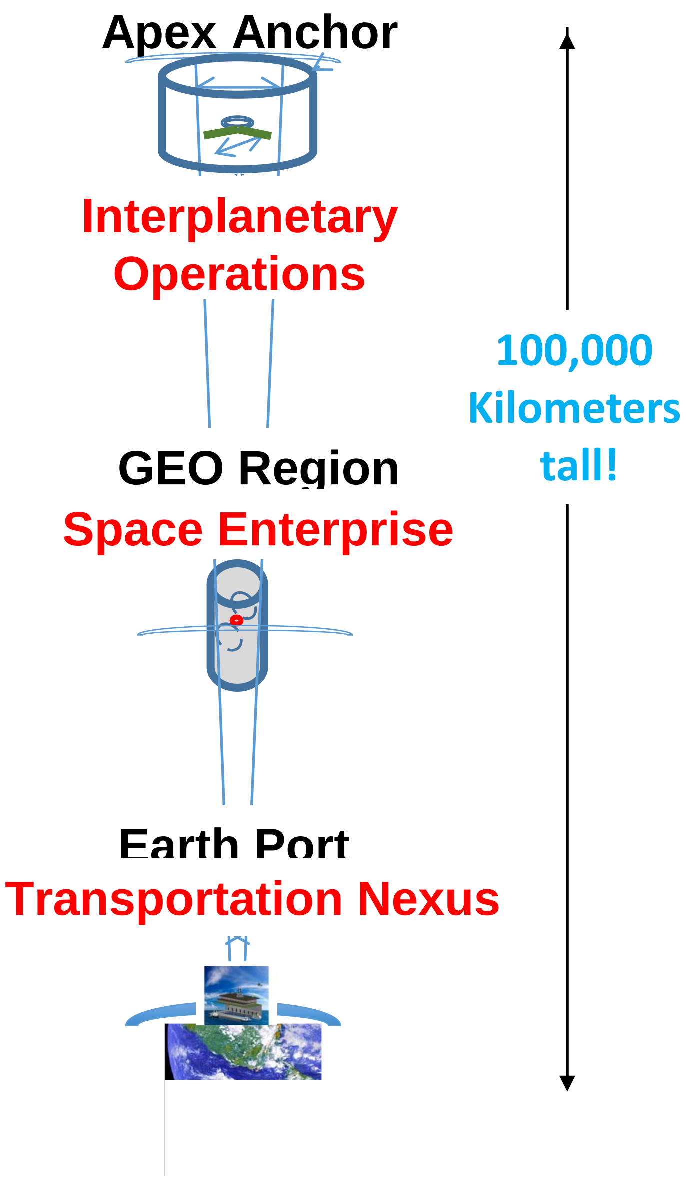
Galactic Harbour

Galactic Harbour Architecture
A Mega Project

This is the transportation story of the 21st century.
Reliable, safe, & efficient access to space.



Galactic Harbour Basics

1. Space Elevator Transportation System is the 'main channel' in the Galactic Harbour.

- *Apex Region*
- *GEO Region*
- *Earth Port*
- *HQ/POC*
- *14 Climbers*
- *2 Tethers*

2. Businesses flourish within the Harbour - as the Space Elevator Enterprise System

- *Business support to Operational Satellites*
- *Interplanetary Efforts within reach*
- *Power and Products delivered to Earth*
- *Research*

Galactic Harbour - The Unifying Vision It is the combination of the Space Elevator Transportation System & the Space Elevator Enterprise System

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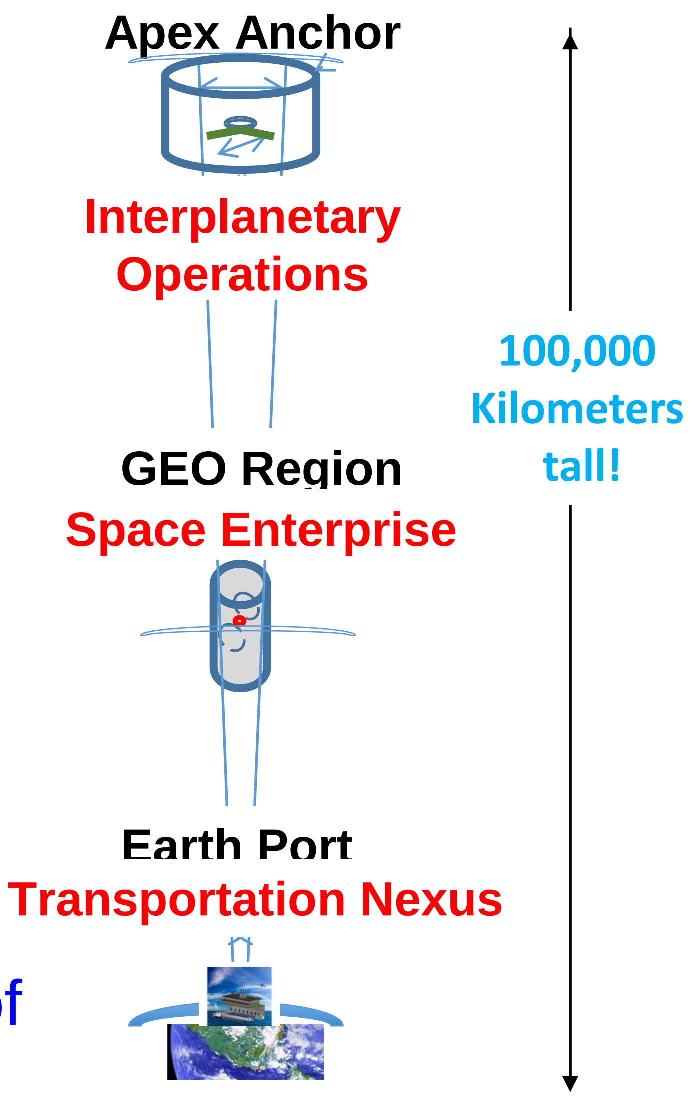
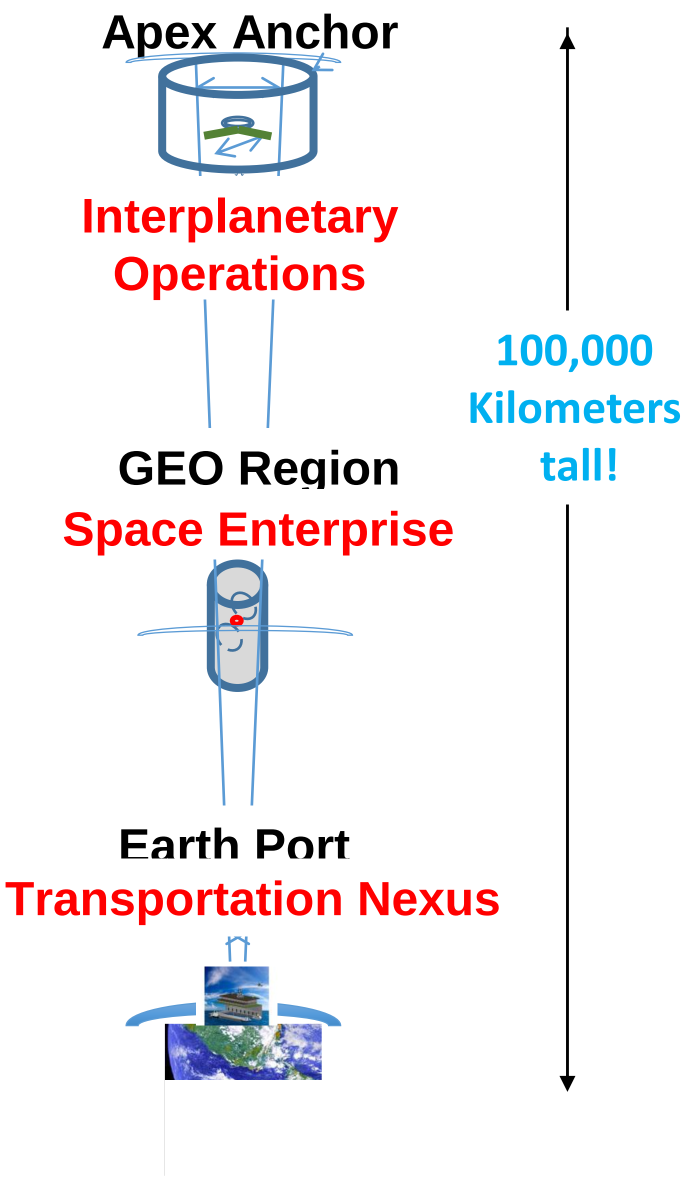
Galactic Harbour Architecture

This is the transportation story of the 21st century. Reliable, safe, & efficient access to space; close at hand.



Galactic Harbour - The Unifying Vision - is the combination of the Space Elevator Transportation System & the Space Elevator Enterprise System

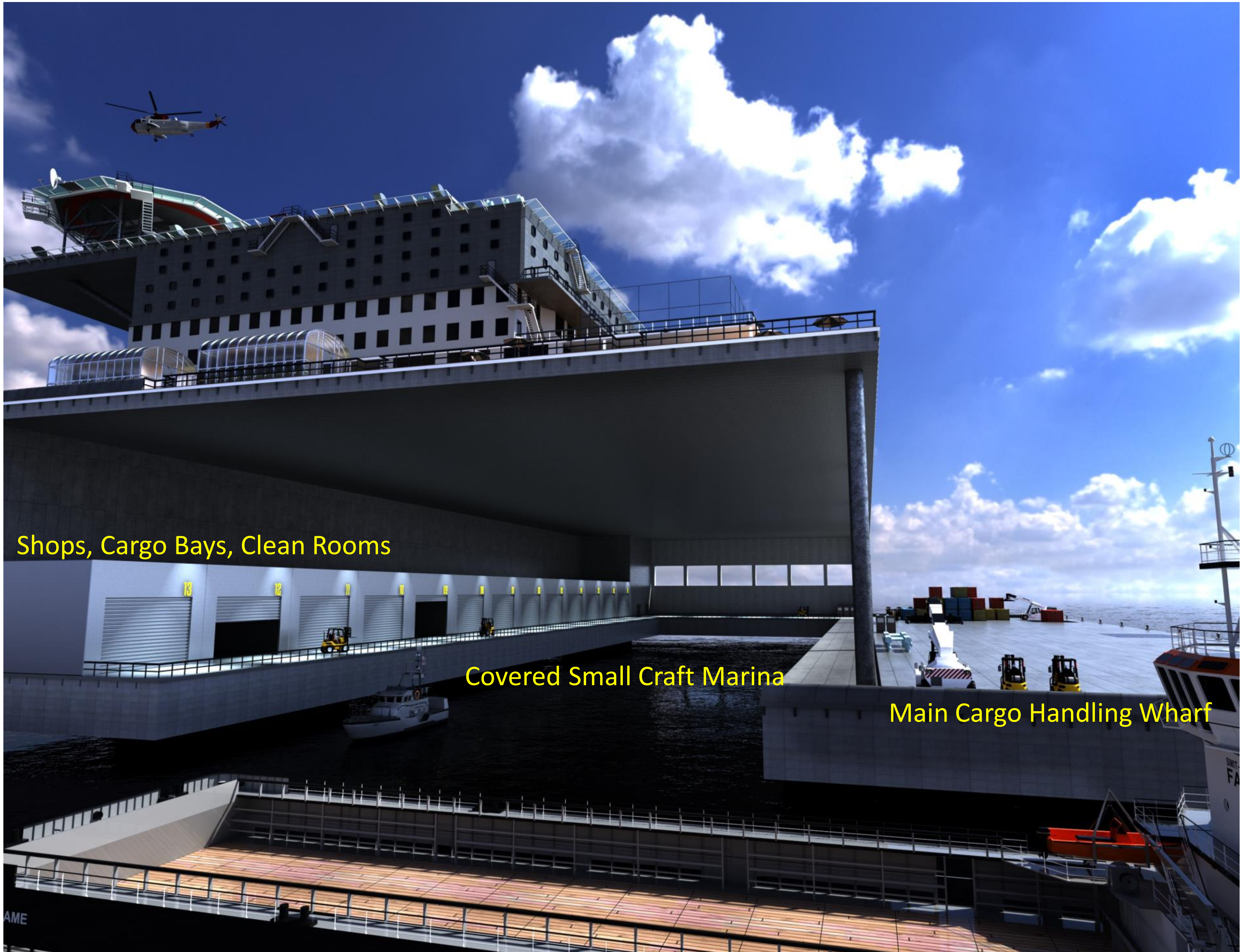
The Earth Port



The Earth Port's Floating Operations Platform
(As Presently Envisioned)

©

The Floating Operations Platform Key Features



The Earth Port Platforms

Tether Terminus

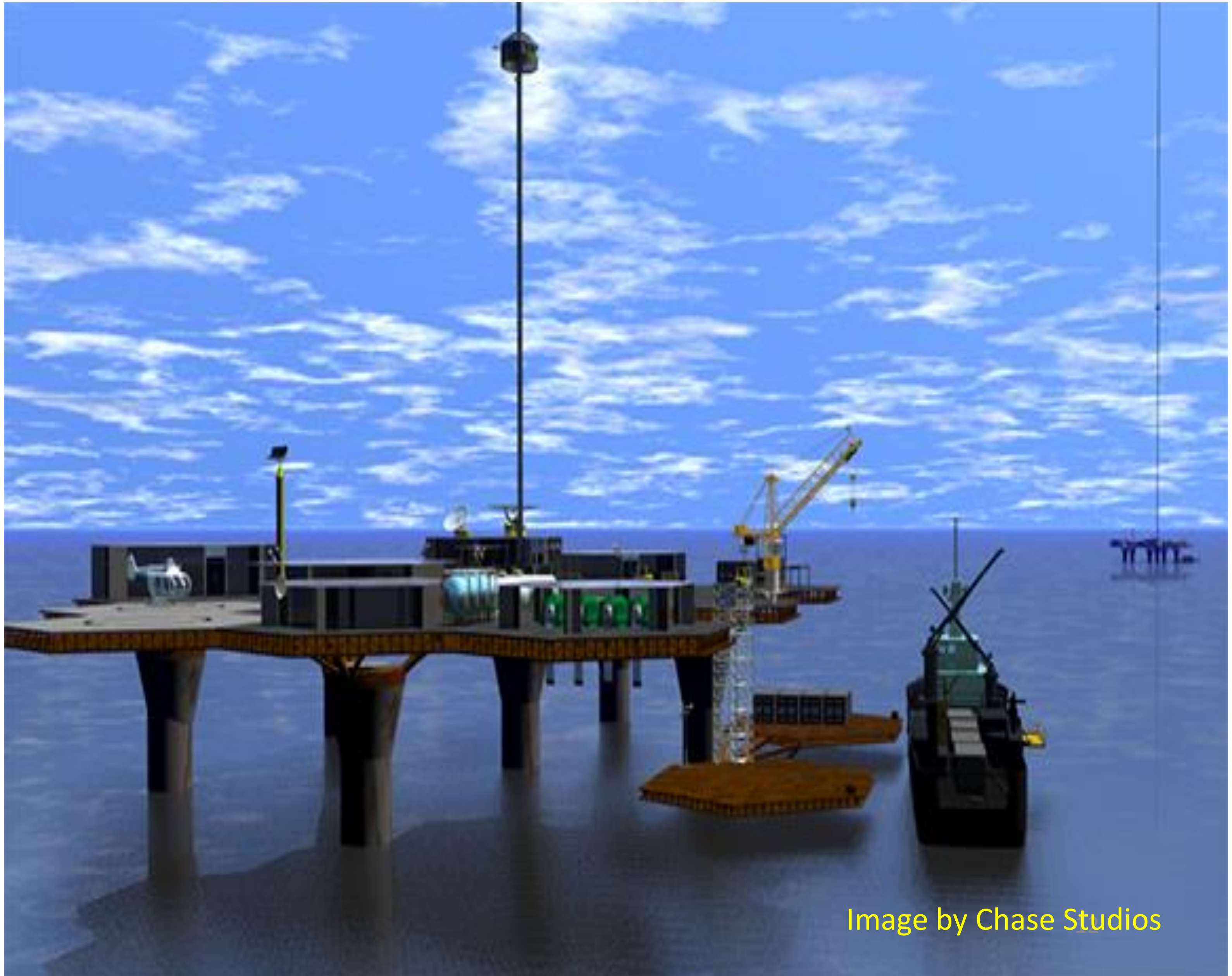
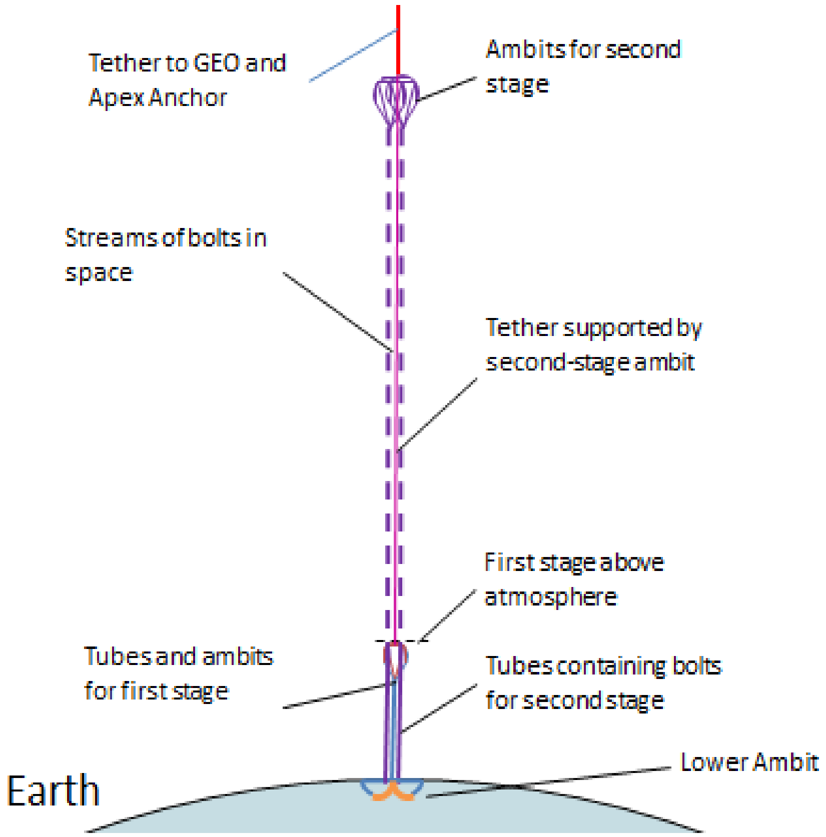


Image by Chase Studios

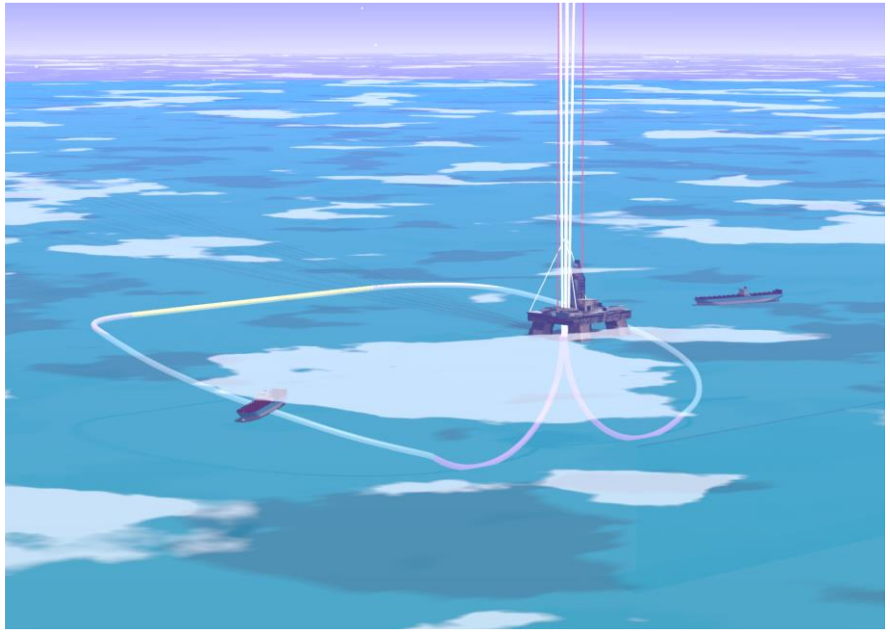
The Multi-stage Space Elevator: an alternative to the single ribbon design



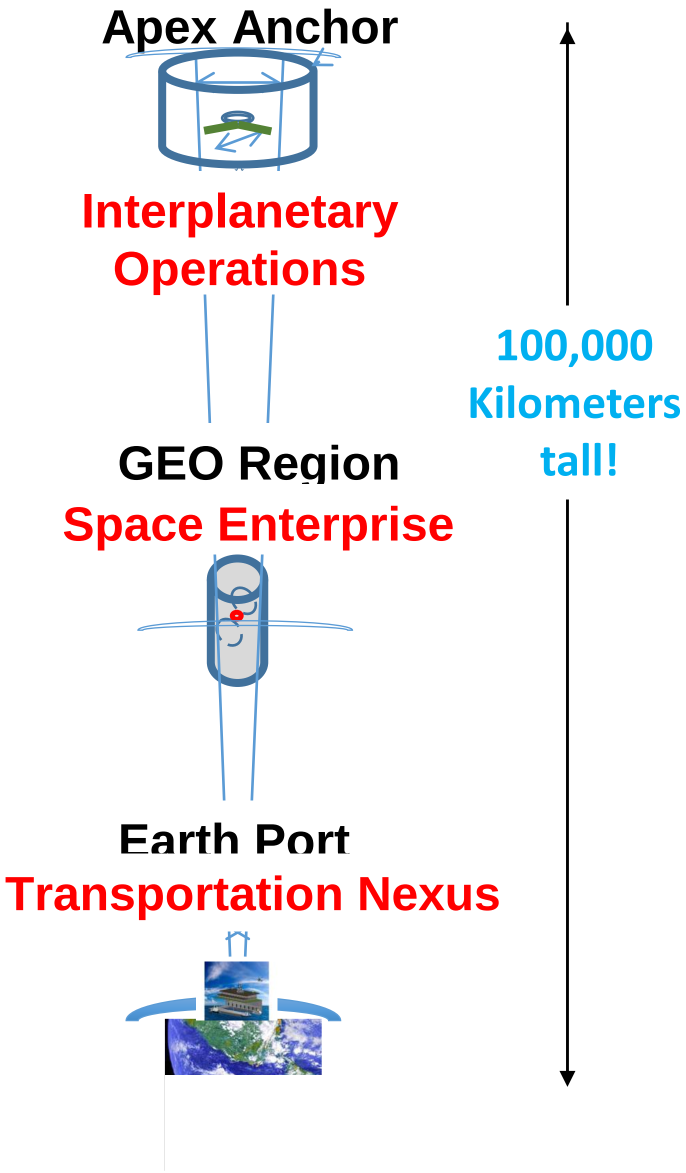
International Space Elevator Consortium ISEC Position Paper # 2019-1

Design Considerations for the Multi-stage Space Elevator

John M. Knapman
Peter Glaskowsky
Dan Gleeson
Vern Hall
Dennis Wright
Michael Fitzgerald
Peter A. Swan



The GEO Region

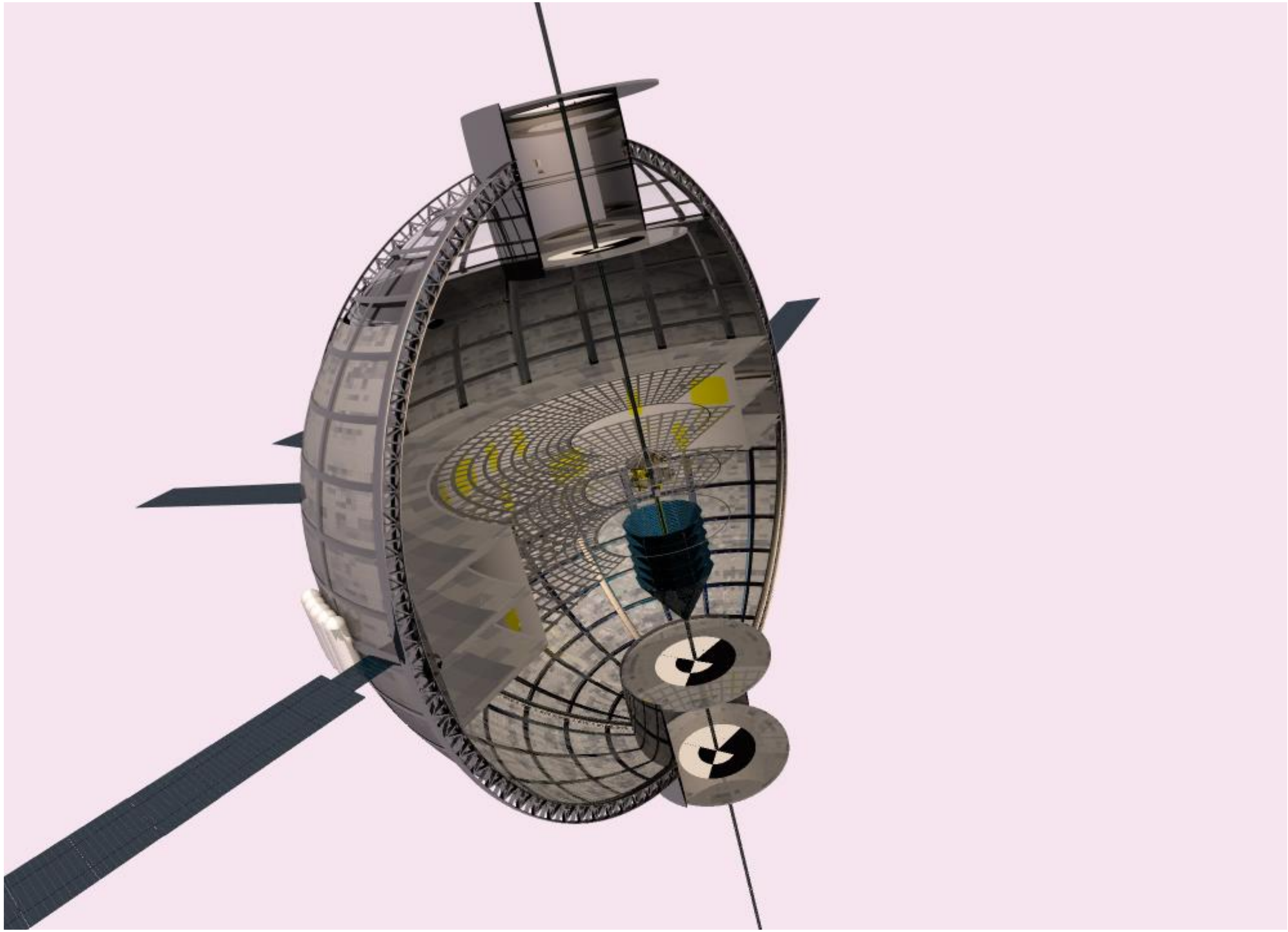


The Old View - 7+ years ago

SPACE ELEVATOR

GEO NODE

As envisioned in the 2013 IAA report

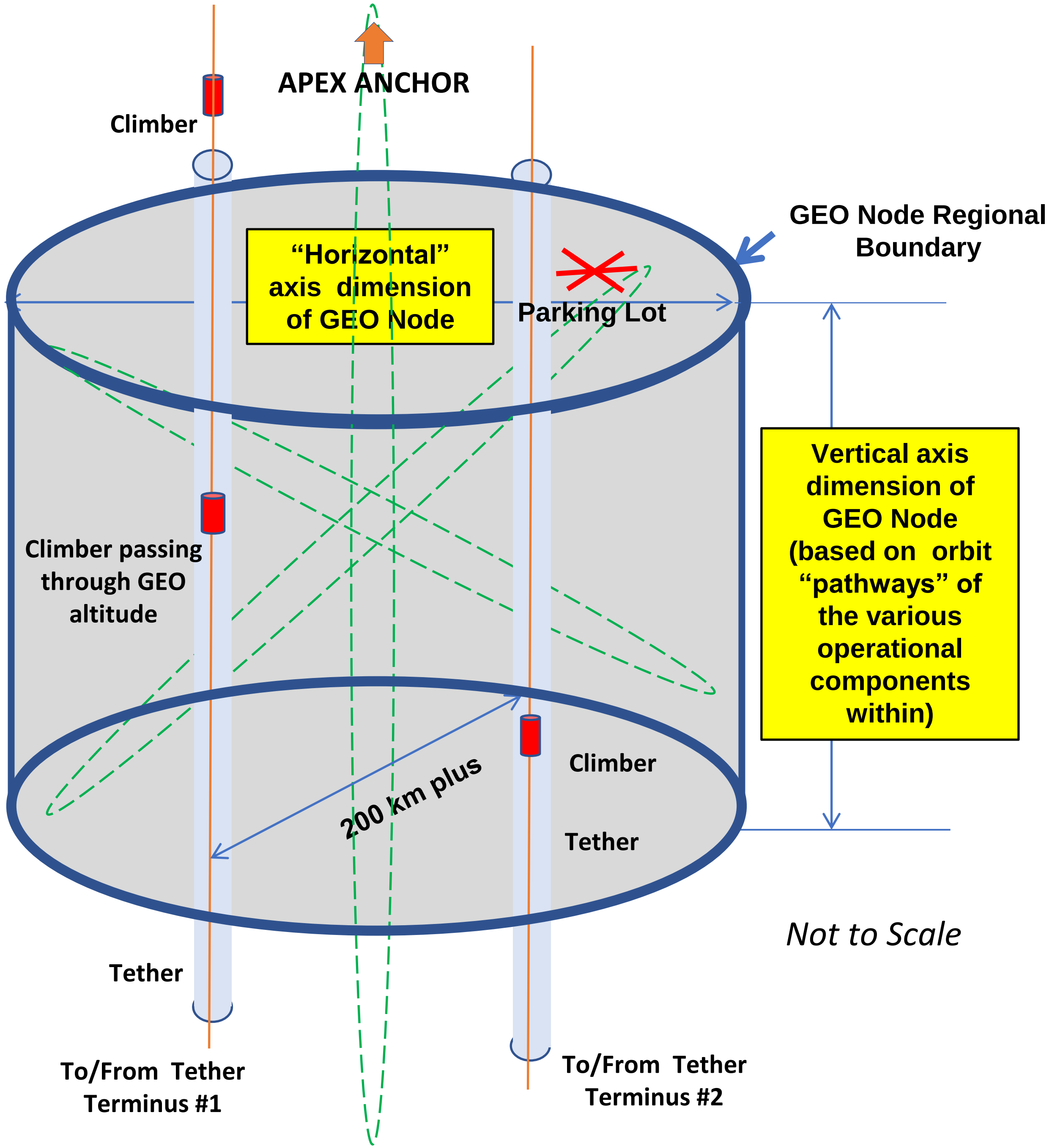


The New View

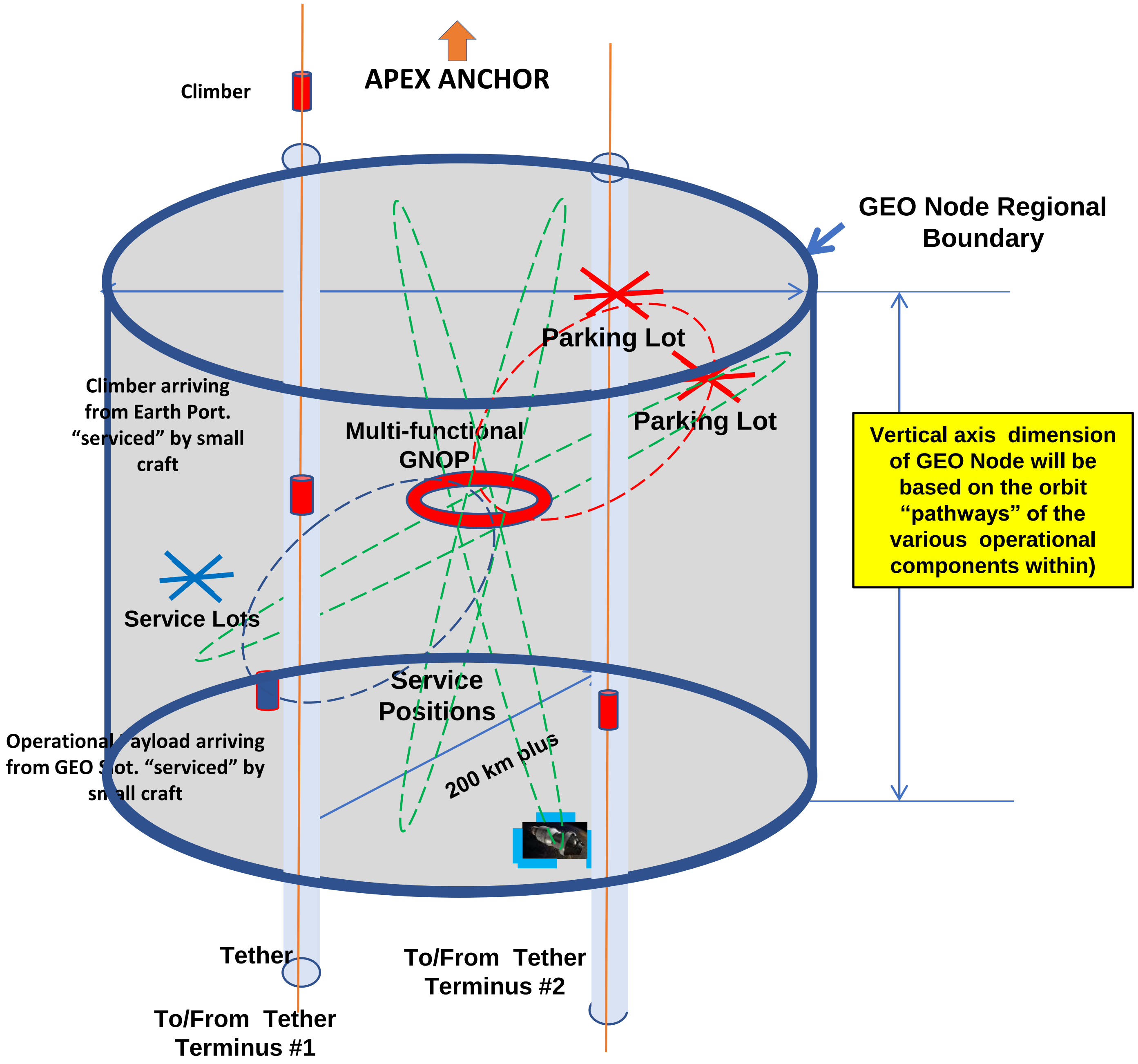
SPACE ELEVATOR

GEO Region

AT IOC

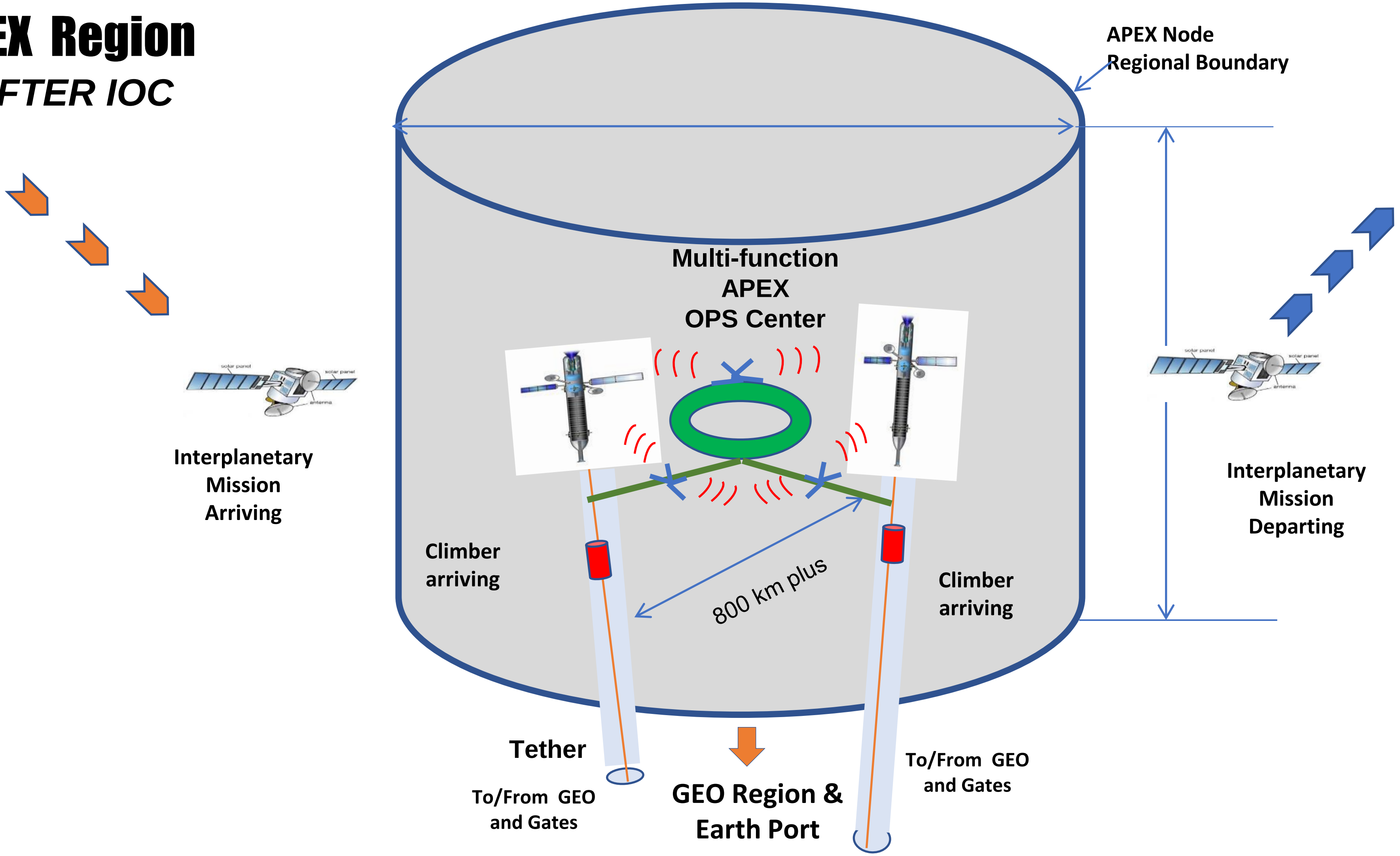


SPACE ELEVATOR
GEO Region
AFTER IOC



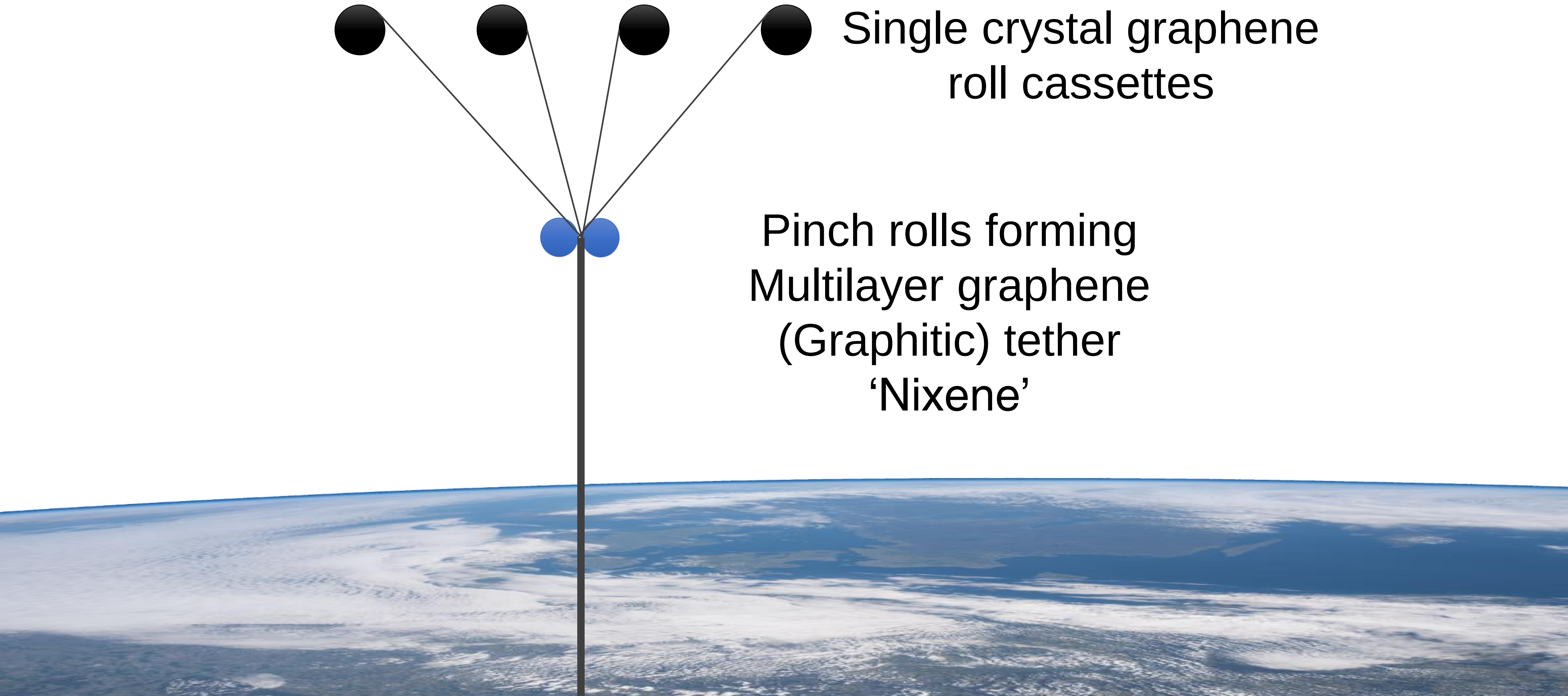
The Apex Region

SPACE ELEVATOR
APEX Region
AFTER IOC



The Tether

Combine the tether layers in orbit…



Architecture Engineering ?

Understand Architecture Engineering? ➔ compare it with System Engineering

System Engineering

1. Assemble the compatible
2. Sub-optimization is inevitable
3. DII / COE
4. Clean Interfaces
5. Modeling and simulation portrays how will operate … anomalies are solved
6. System Performance
7. Block Upgrades
8. System to Segments to …
9. BITE

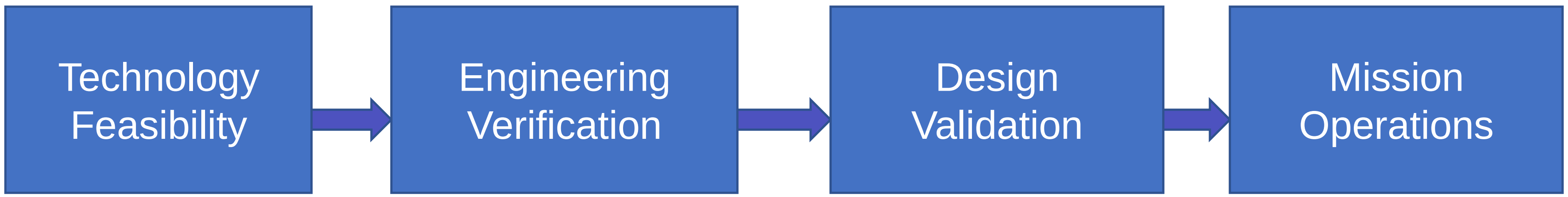
Architecture Engineering

1. Assemble the incompatible
2. Optimization is an imperative
3. OPEN
4. Intelligent Interfaces
5. Modeling and simulation projects operational alternatives … anomalies are avoided
6. Job Success
7. Adaptive Evolution
8. Domains and sub domains and …
9. Agents and Synoptic Monitoring

Technology Maturity and Readiness

Galactic Harbour Technology Development Strategy
-- Architecture Engineering 101 --

Stages of "Maturity" Roadmap



What are we doing?

Phase One Technology Feasibility & Readiness (based on a concept baseline)

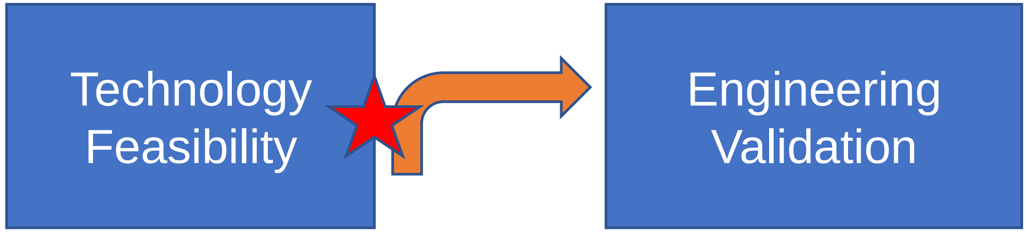
1. **Document technology readiness state.**
2. **Establish readiness level rationale for all portions of the Program.**
3. **Set Success Criteria regarding Engineering Approach Verification**

ISEC Position Paper # 2014-1; "Space Elevator Architecture and Roadmaps";

Galactic Harbour Technology Development Strategy
-- Architecture Engineering 101 --

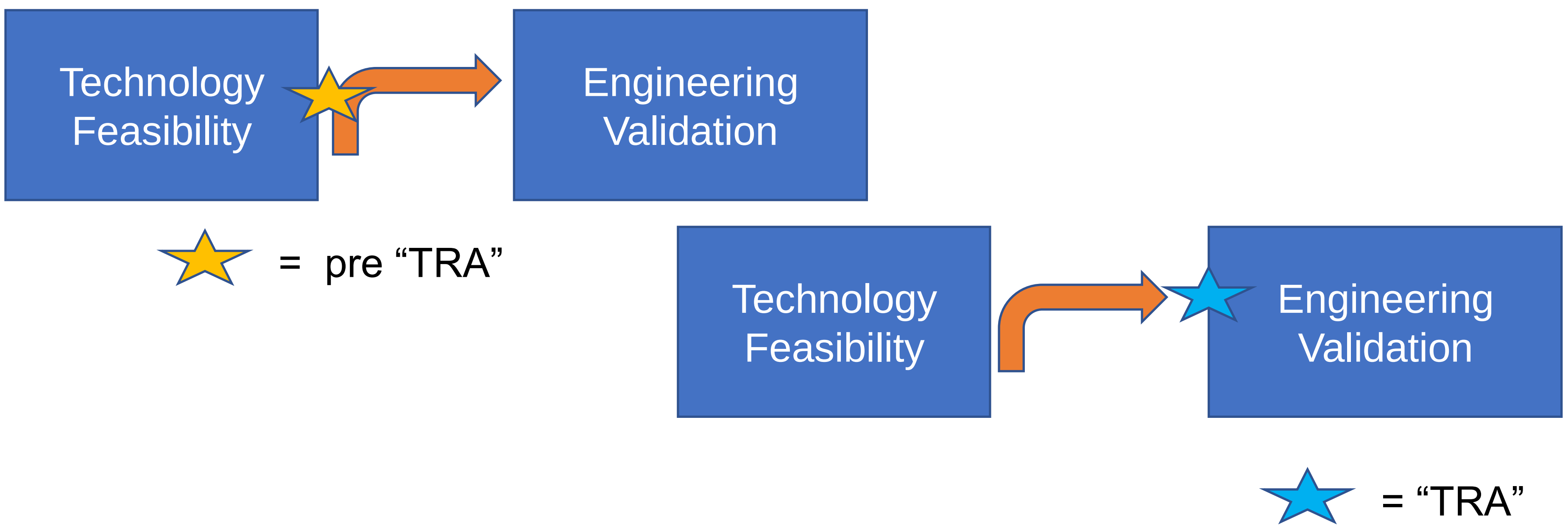
ISEC's preliminary Technology Readiness Assessment:

"pre TRA" = Start along its demonstration roadmap" …



ISEC's preliminary Technology Readiness Assessment (TRA):

"Start along the Engineering Validation demonstration roadmap" …



What will we be doing?

Phase Two -- Engineering Approaches.

Phase two is driven by six major activities:

1. Determine if it can be built:

2. Examine Industry's technology maturation approaches:

3. Assess schedule & technical risk:

4. Delineate "On Ramp" Criteria:

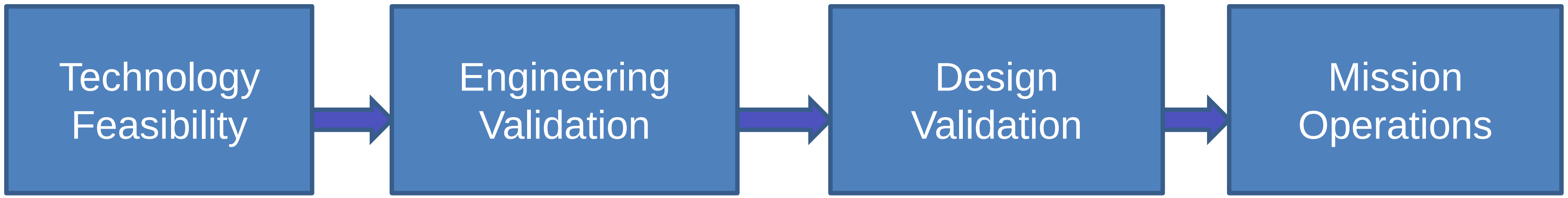
5. Set criteria and standards regarding Design Validation:

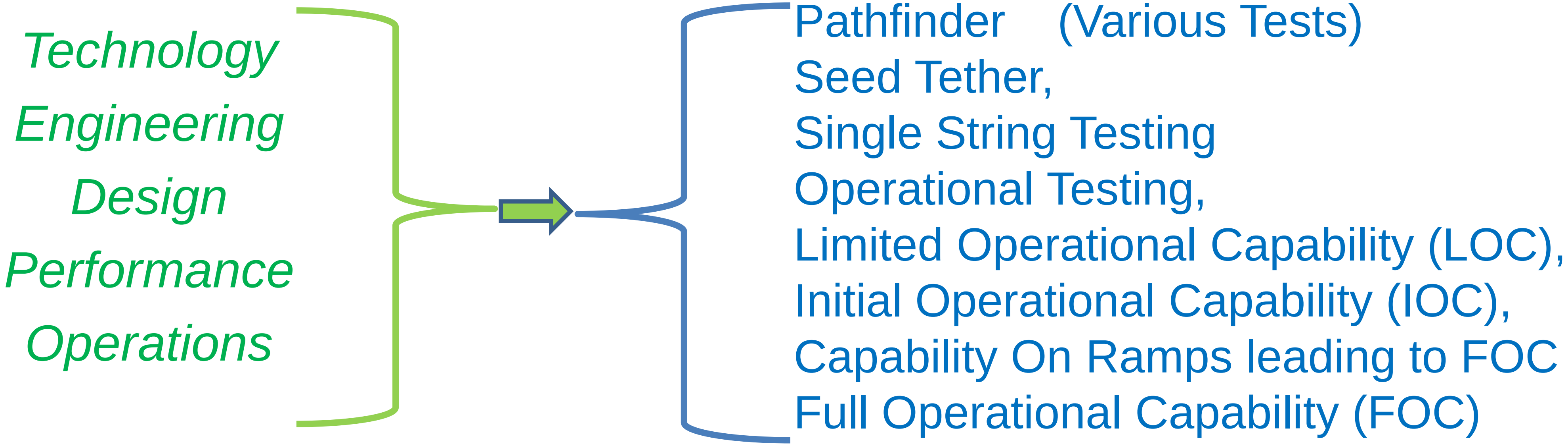
6. Baseline Technical Performance:

Space Elevator Development Phases “SEQUENCES”

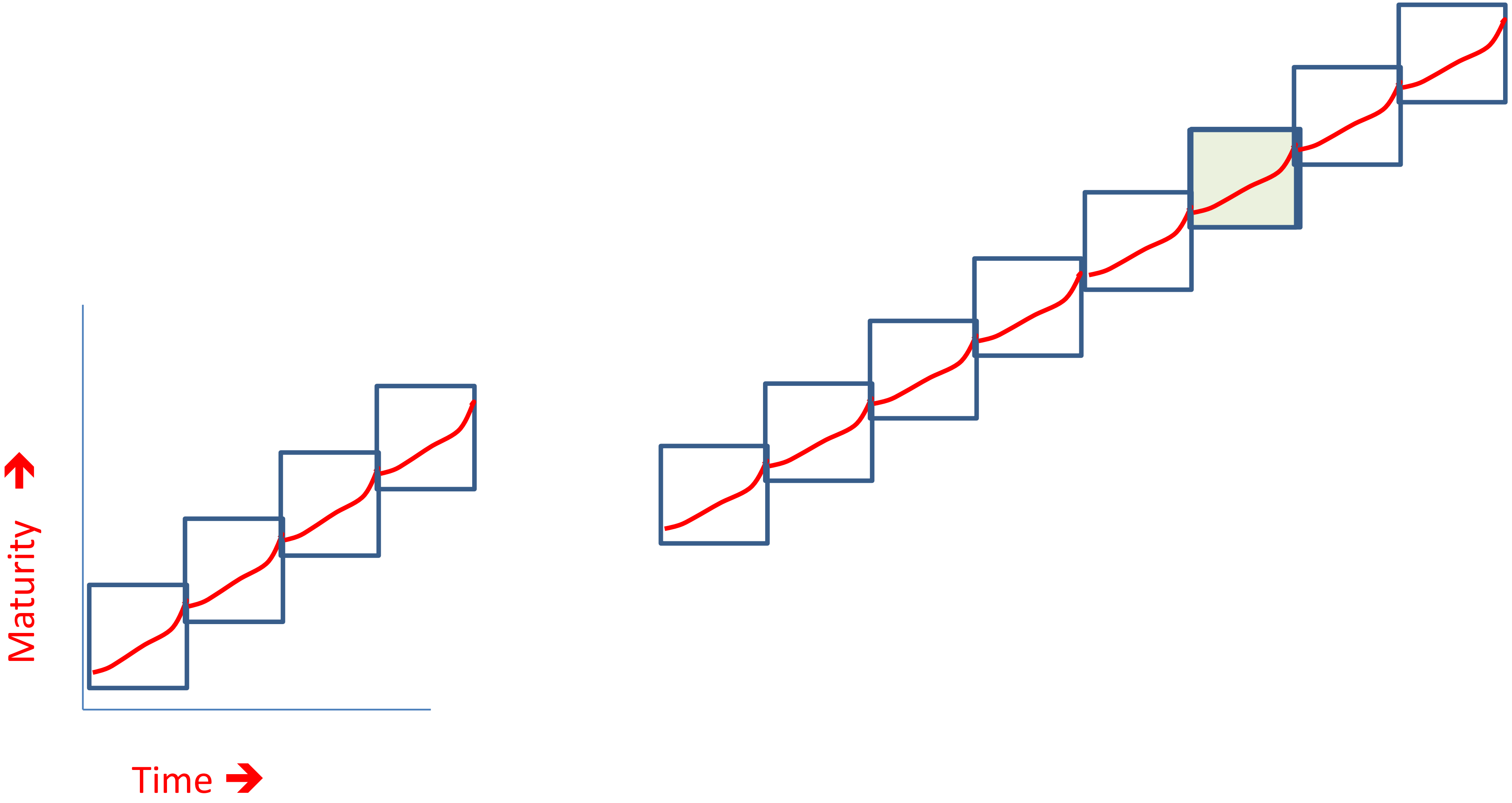
1. Pathfinder
2. Seed Tether,
3. Single String Testing
4. Operational Testing,
5. Limited Operational Capability (LOC),
6. Initial Operational Capability (IOC),
7. Capability On Ramps leading to FOC
8. Full Operational Capability (FOC)

SEQUENCES
Levels of Technical Readiness





Visualizing READINESS IOC



The Transportation Elixir

Apex Region

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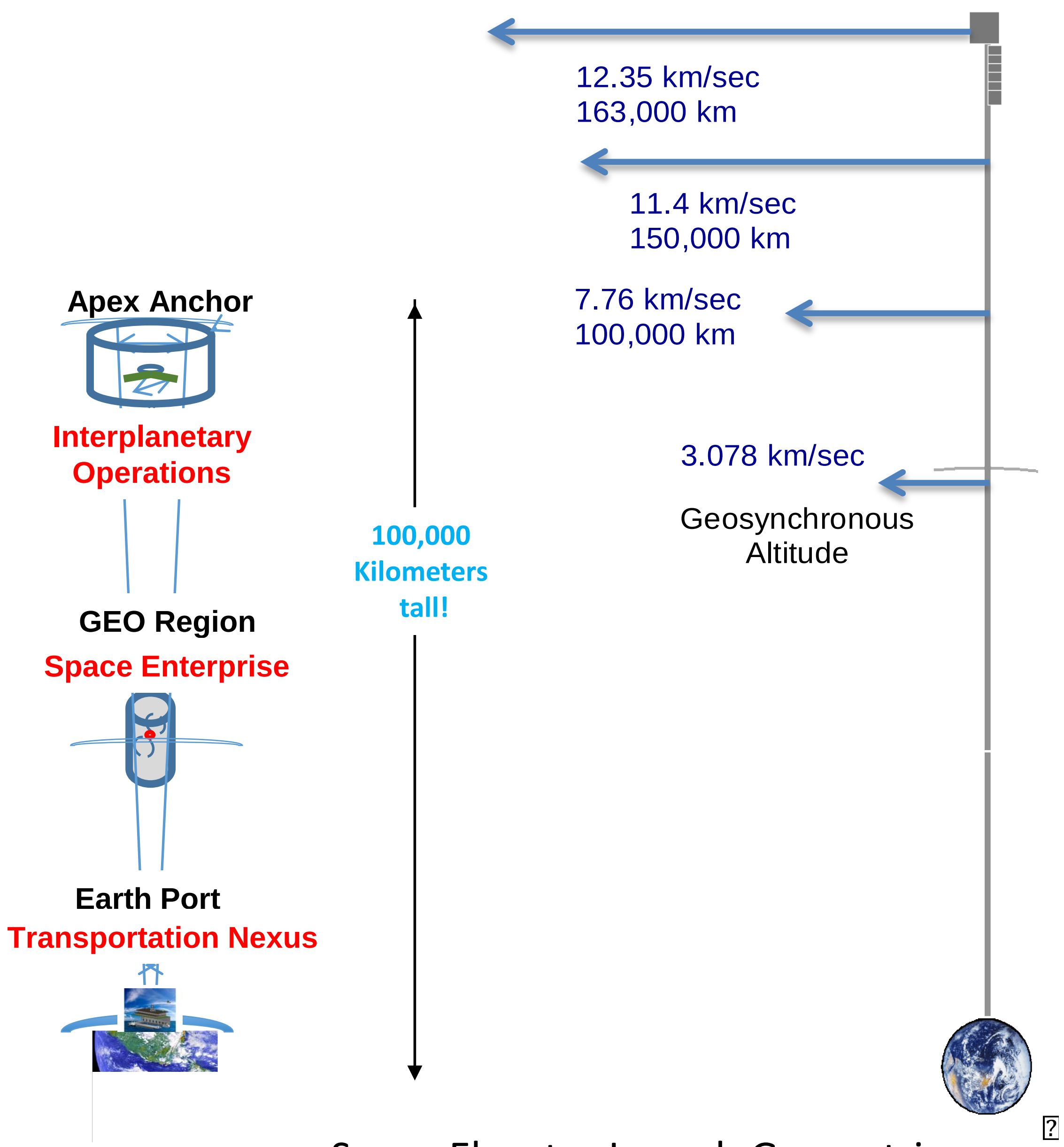


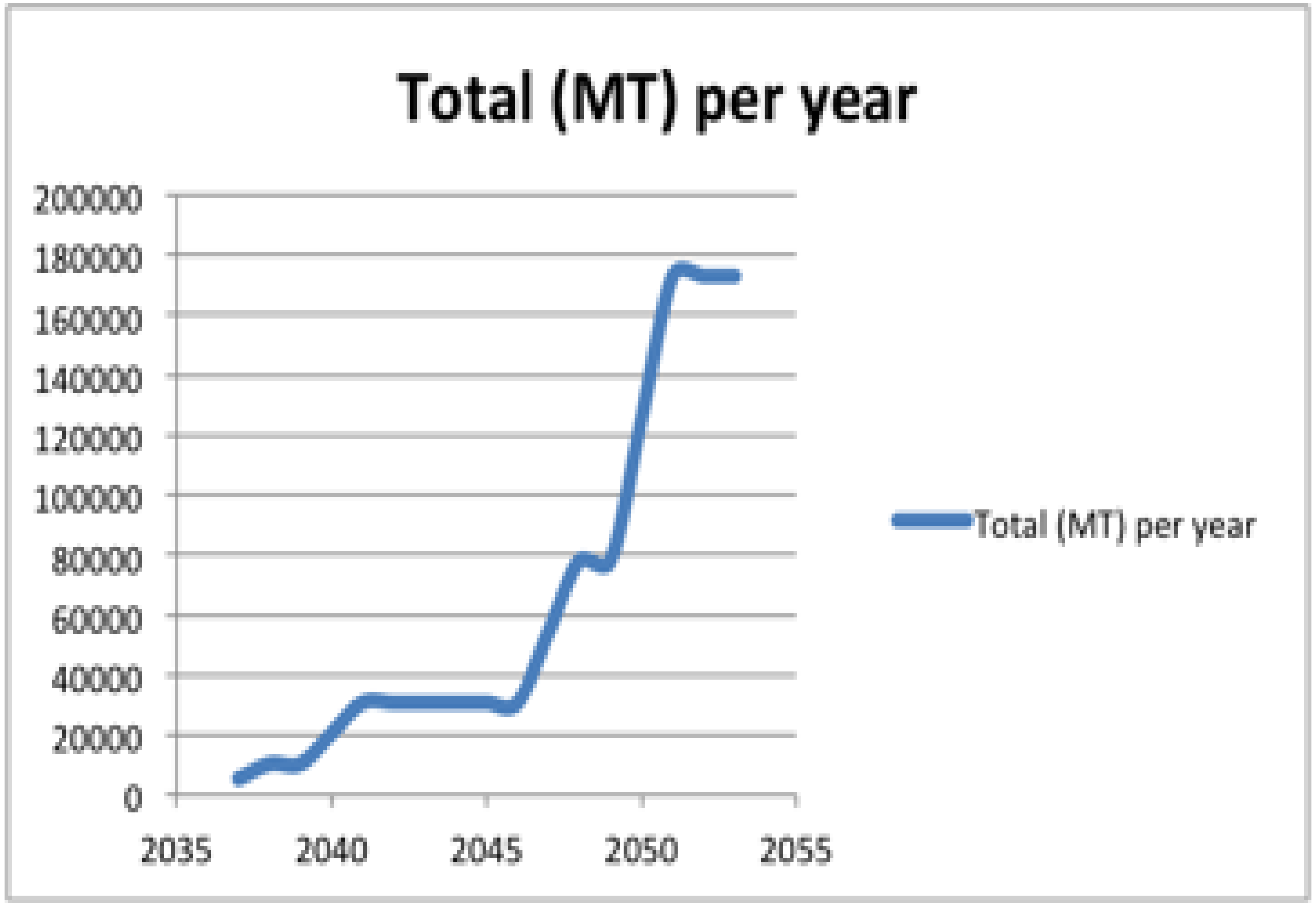
Space Elevator Launch Geometries

Galactic Harbour – velocity on account

Torla, James and Matthew Peet,

"OPTIMIZATION OF LOW FUEL AND TIME-CRITICAL INTERPLANETARY TRANSFERS USING SPACE ELEVATOR APEX ANCHOR RELEASE: MARS, JUPITER AND SATURN,"

International Astronautics Congress (IAC-18-D4.3.4), Washington D.C., 2019.



Interplanetary Transportation Throughput

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

Table 13-V. Projected Demand [MT/yr]

Interplanetary Transportation REQUIREMENTS

Interplanetary Transportation Network

Today’s Intermodal container-based shipping network serves the Planet Earth

The Galactic Harbour expands Earth's Transportation Network to the Solar System

Thank you for your time

This is the Transportation story of the 21st Century
We will keep you informed

"Fitzer"

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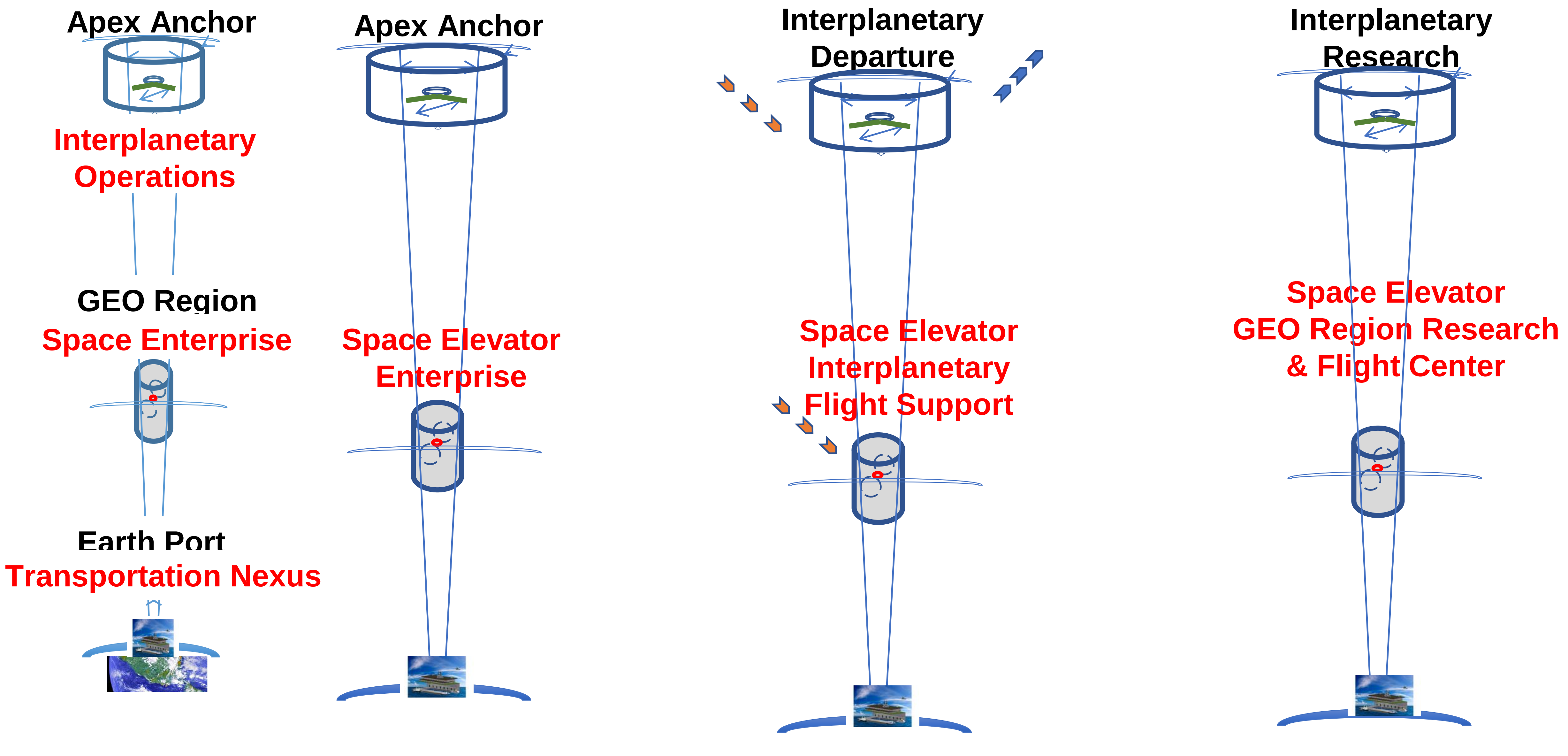
ISEC The International Space Elevator Consortium

You can become a member of ISEC starting from just $25

www.isec.org

Family Of Elevators



What are we doing?

Phase One Technology Feasibility & Readiness

1. **Document technology readiness state.** Determine if the technologies are State of Art (SOA) or State of the industry (SOI) or State of the Market (SOM). "SOA" means that only one industry member holds the critical technology; "SOI" means that a few competent industry members can play; and "SOM" means that the technology is widely available and widely used.
2. **Establish readiness level rationale for all portions of the Program.** Given that the technology availability has been demonstrated (SOA v SOI v SOM … etc.) the level of readiness can be established for program segment, component or subsystem. This taxonomy of readiness will be well understood by, and documented in an official readiness assessment per segment; using the rationale set here.
3. **Set Success Criteria regarding Engineering Approach Verification.** Prudent acquisition approaches call for an early preliminary design review (PDR). The PDR is an examination to show that the projected engineering approaches are valid. In this consideration "engineering verification" means that we can build it. If the technology exists, it can be included in a design based purely upon technology maturity. If a component is SOM, SOI or SOA, or is a TRL level 6, some engineering verification information is needed to get through the process. "Show me" means a lot at this point.

ISEC Position Paper # 2014-1; "Space Elevator Architecture and Roadmaps";

What are we doing?

Phase Two -- Engineering Approaches.

This Phase will begin soon after a worthy milestone. Seek a wide range of engineering objectives from various members of the industry. Some efforts might reflect a competitive construct of one segment's envisioned solution, while another effort might be a more collaborative activity. This Phase two activities are driven by six major activities:

1. **Determine if it can be built:** This is the fundamental question. Describe the segment concepts envisioned and assess the various engineering approaches being considered. Ask industry if the engineering approach is valid and does it incorporates the results of an ongoing technology maturation effort.
2. **Examine Industry's technology maturation approaches:** **R**eview a sample of these roadmaps in industry. It will be clear from the roadmaps that the range and number of needed engineering verification tests are substantive.
3. **Assess schedule & technical risk:** This assessment needs to be very real. Multiple tests, and simulations are the path to ISEC program success; and they are the basis of a long sequence of engineering and design judgments. Conducting the numerous tests, resulting in the proper test data and performance insights is in itself a risky set of ventures. However, proceeding without thorough testing would be beyond risky.
4. **Delineate "On Ramp" Criteria:** Based upon the information on emerging technologies that will not be mature in time, they should be deferred. This is not simply delay; but rather a considered approach of when that capability is ("really") needed and whether subsequent maturity and testing will be manifest.
5. **Set criteria and standards regarding Design Validation:** By the end of Phase Two ISEC should be able to determine whether or not the Space Elevator can be build by determining the efficacy of specific design approaches. Those design criteria and design standards need thorough evaluation for the sake of technology, schedule and/or cost risk.
6. **Baseline Technical Performance:** By the end of Phase Two, the performance of the envisioned concept can be predicted and will be "baselined."

ISEC Position Paper # 2014-1; "Space Elevator Architecture and Roadmaps";

Preliminary Technology Readiness Assessment

1. The Earth Port is buildable with today's available technologies and engineering expertise.
2. The Headquarters / Primary Operations Center is buildable today.
3. The Tether Climber is similar to a today's satellites, and ISEC sees no technology challenge to the construction of the Climber.
4. The GEO Node and Region technology needs are understood and ISEC assesses that the most of the GEO Node's Transportation System components can be built now.
5. The Apex Anchor will be a challenge. Its role is key to the building of the Space Elevator, but it is neither a technological nor engineering obstacle. The Apex Anchor can support the Space Elevator Transportation System; and could be built in the near future.
6. The Tether material is the pacing item for the development of the Space Elevator. Currently, there are at least three viable materials that could mature into the needed "strong enough and long enough" material for a Space Elevator Transportation Tether; 100,000 kms long and strong enough to support multiple Climbers.
7. The other voiced challenge to the Space Elevator Transportation System faces is collision avoidance. ISEC, and others, have studied the issue, and collisions are much less likely than most think. Even so, the Space Elevator Transportation System will be advised of approaching debris; even debris smaller than a pebble – in sufficient time to avoid it. Further, the Space Elevator Transportation System will work with the FAA's Space Traffic Management program ensuring that the Tether operates only within uniquely assigned space locations. This traffic management approach will keep other operating space systems safely separated from the Elevator.