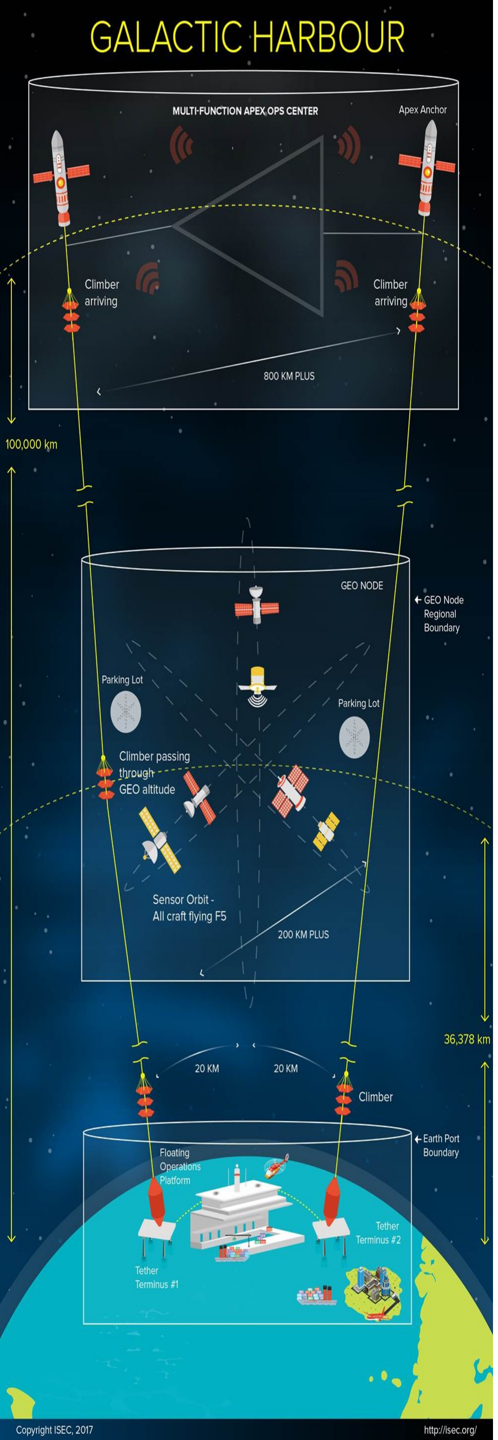

Architecture Engineering and the Galactic Harbour

IAC-21-D4.3.3

SPACE ELEVATORS ENTERING ENGINEERING DEVELOPMENT - NOW

Michael Fitzgerald* and Peter Swan**

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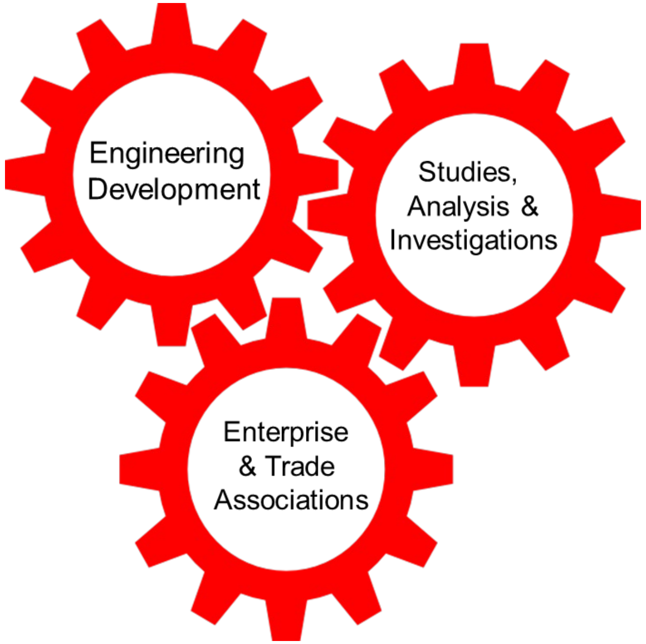
Vision

Space Elevators are the Green Road to Space while enabling humanity's most important missions by moving massive tonnage to GEO and beyond. They accomplish this safely, routinely, inexpensively, and daily - all while being environmentally neutral.



Architecture Engineering

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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. MS & A lets you see how it operates … 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. MS & A projects operational alternatives- anomalies are avoided
6. Mission Success
7. Adaptive Evolution
8. Domains and sub domains and …
9. Agents and Synoptic Monitoring

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Assemble the incompatible

Architecture Engineering 101

It is the nature of the Space Elevator that its systems are “not compatible”. The Earth Port is to be designed and built to operate in the middle of the Pacific Ocean, while the Apex’s Anchor is in “outer space”. At the Architecture level, the Space Elevator’s *several systems must be integrated together* for the sake of mission success.

The systems will not be compatible at the system-to-system interfaces. The multiple Climbers will be traversing the Tether over huge distances. Architecture Engineers must overcome such things.

Intelligent Interfaces

Architecture Engineering 101

At the architecture level, interfaces take on a different role.

Interfaces will have two fundamental functions:

1. Connect and
2. Make compatible the various parts of the diverse architecture.

The “make compatible” function is an architecture unique trait and likely must be an adaptable trait; growing and changing as the architecture morphs to meet the changing mission. In that sense, interfaces are intelligent.

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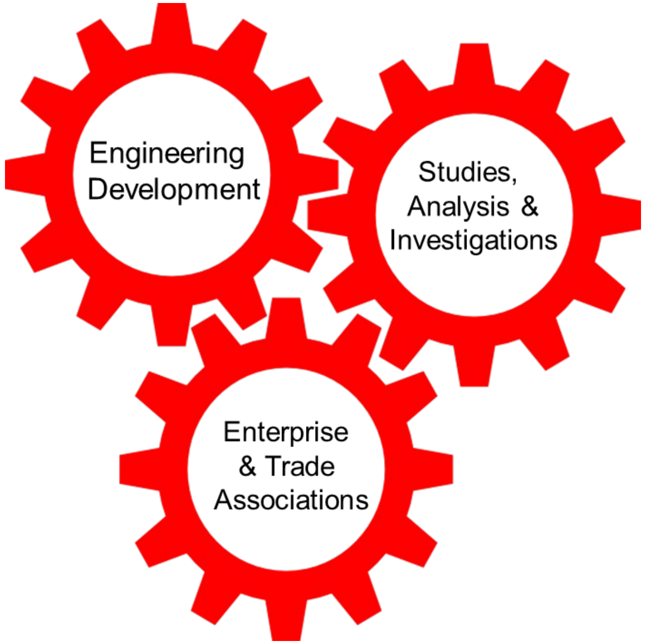
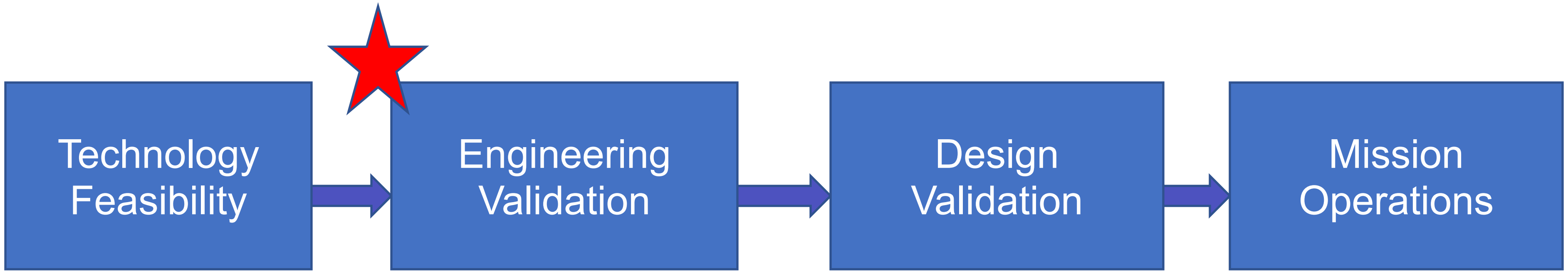


Technology Maturity and Readiness

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

Stages of “Maturity” Roadmap



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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";

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";

SEQUENCES
Levels of Technical Readiness

Technology Feasibility → Engineering Validation → Design Validation → Mission Operations

Technology
Engineering
Design
Performance
Operations

→

1. Pathfinder (Various Tests)
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)

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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***

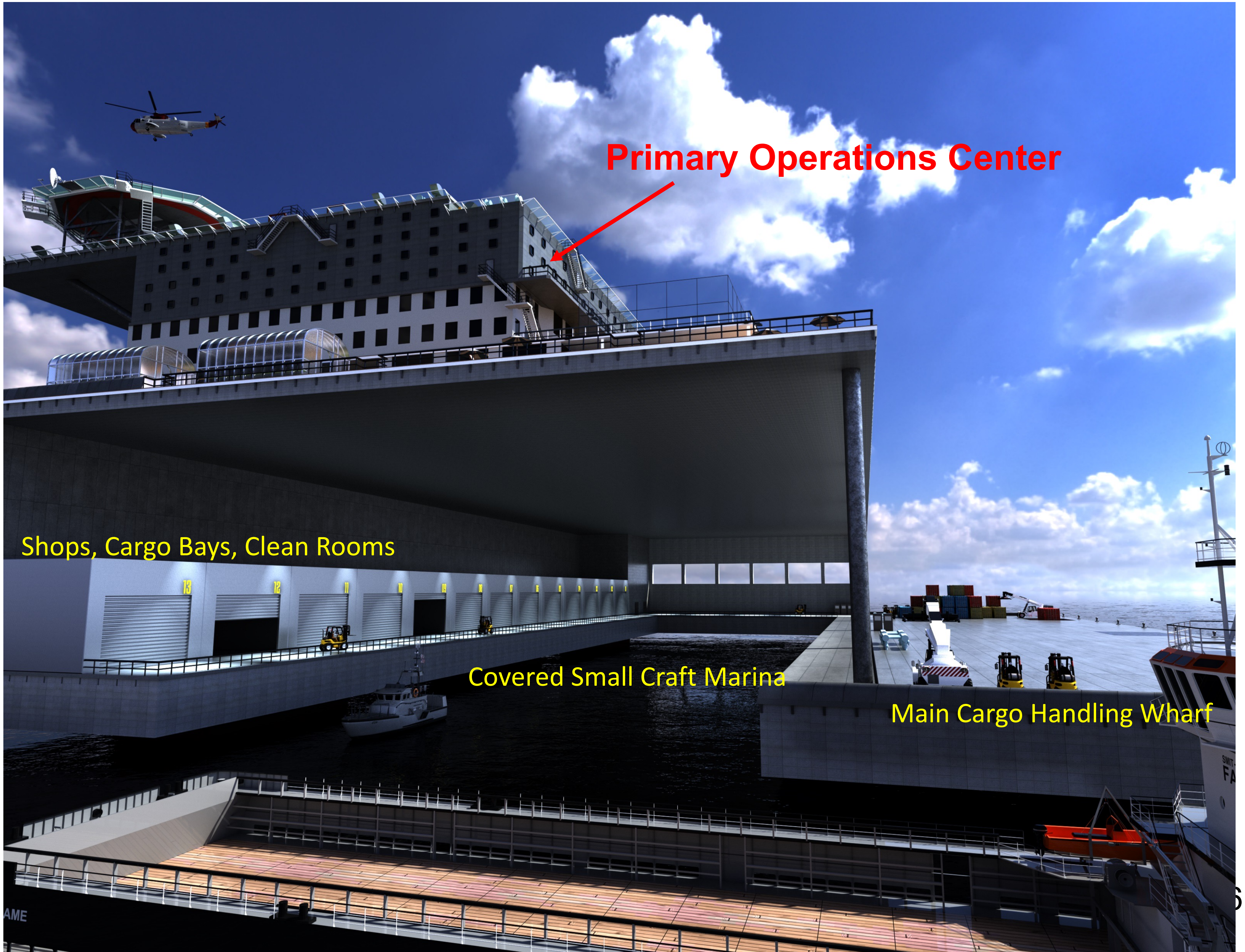
Galactic Harbour - The Unifying Vision It is the combination of the Space Elevator Transportation System & the Space Elevator Enterprise System

Los Angeles and Long Beach Harbor

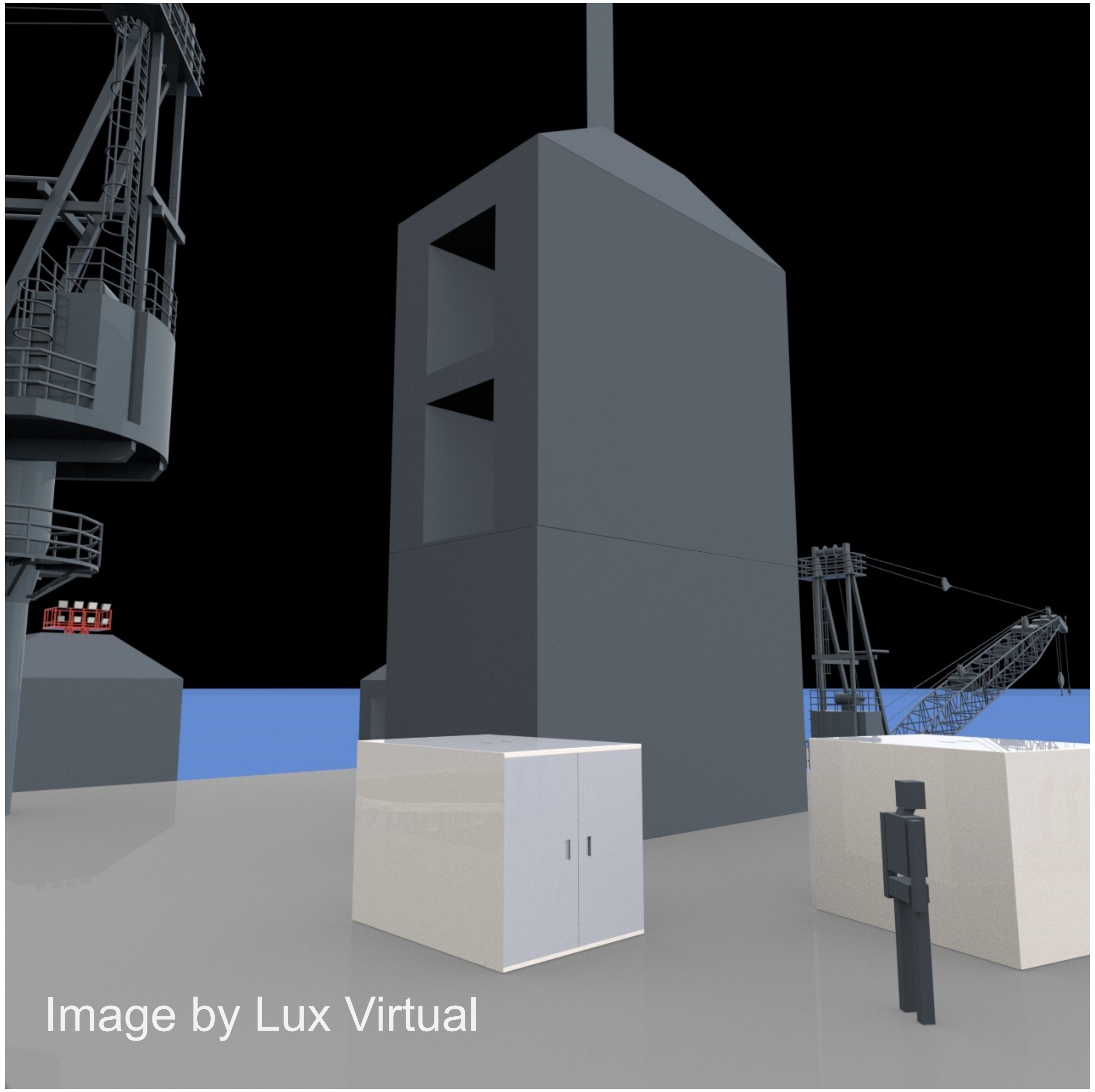
The Earth Port

Floating Operations Platform

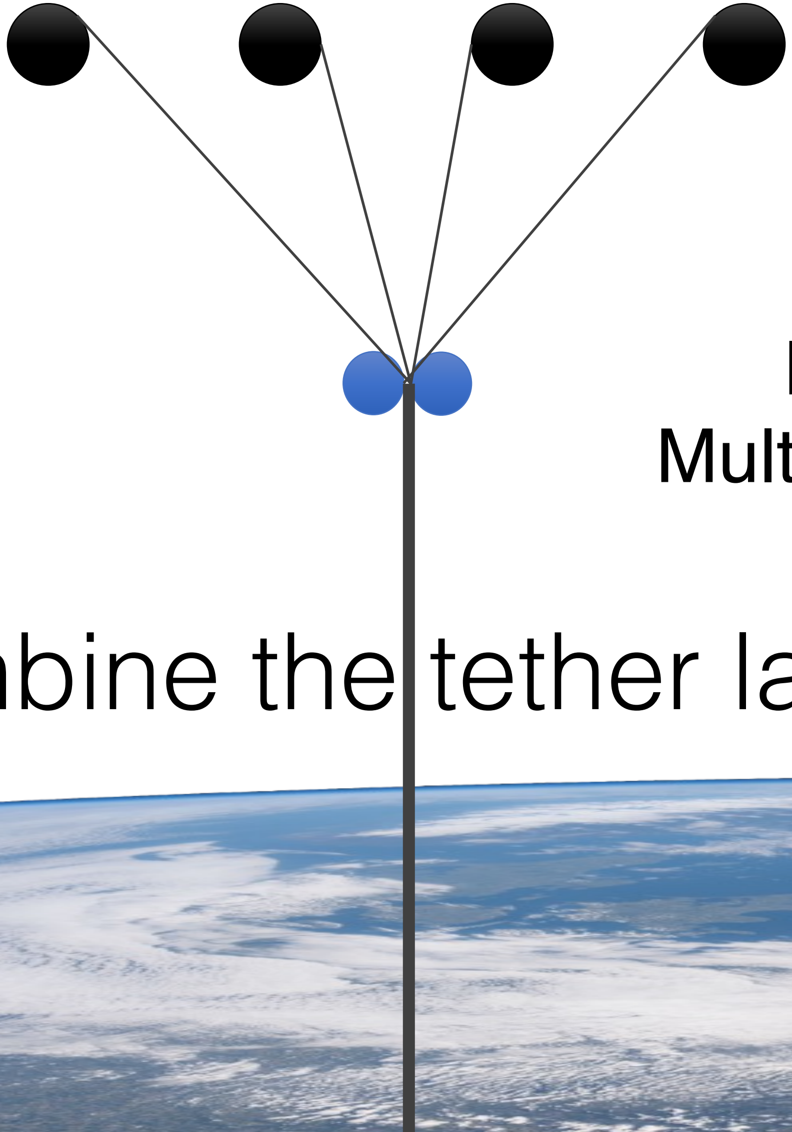
The Floating Operations Platform Key Features



Cargo destined for GEO being loaded at Tether Terminus



The Tether



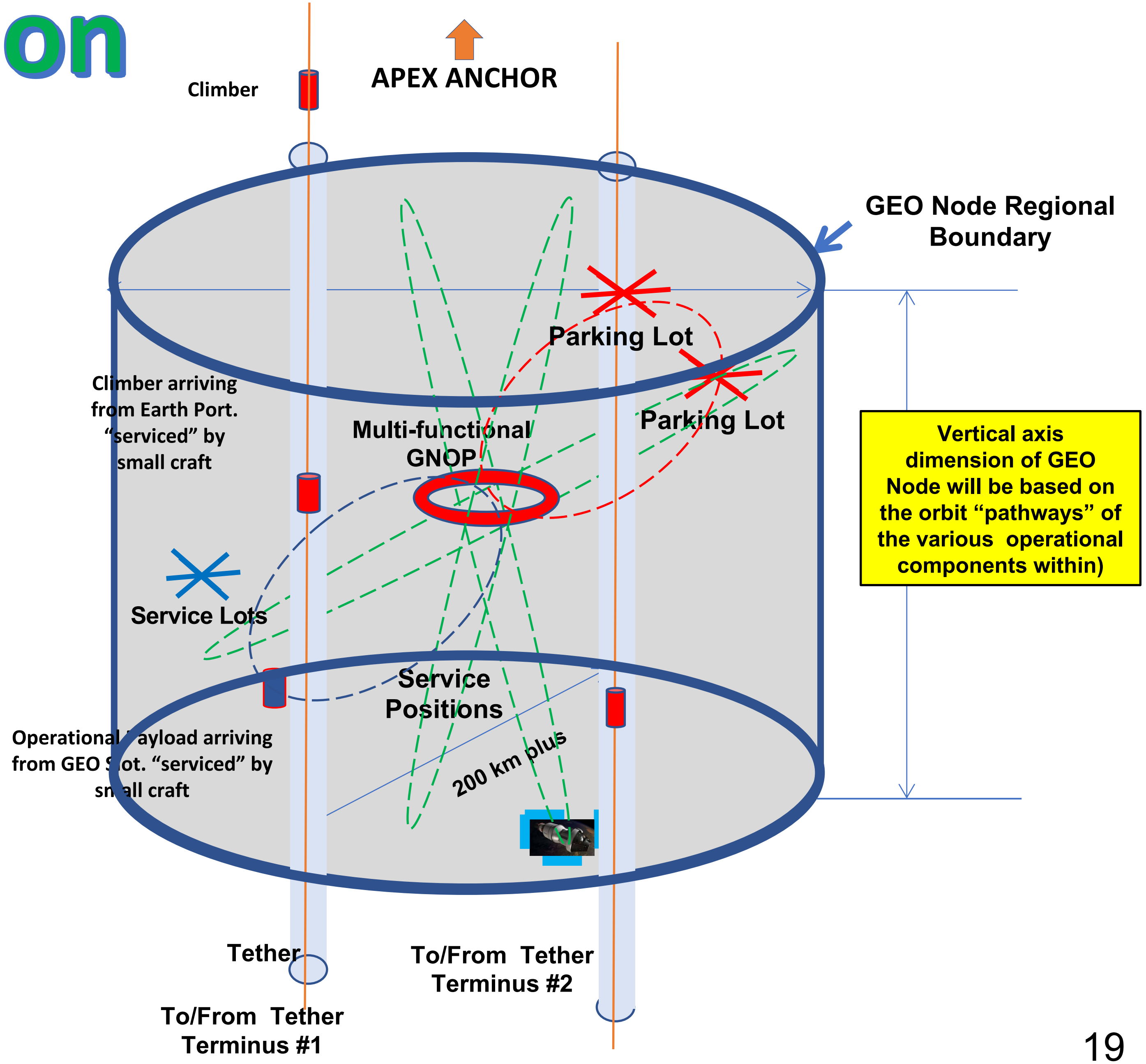
Single crystal graphene roll cassettes

Pinch rolls forming
Multilayer graphene tether
‘Nixene’

Combine the tether layers in orbit…

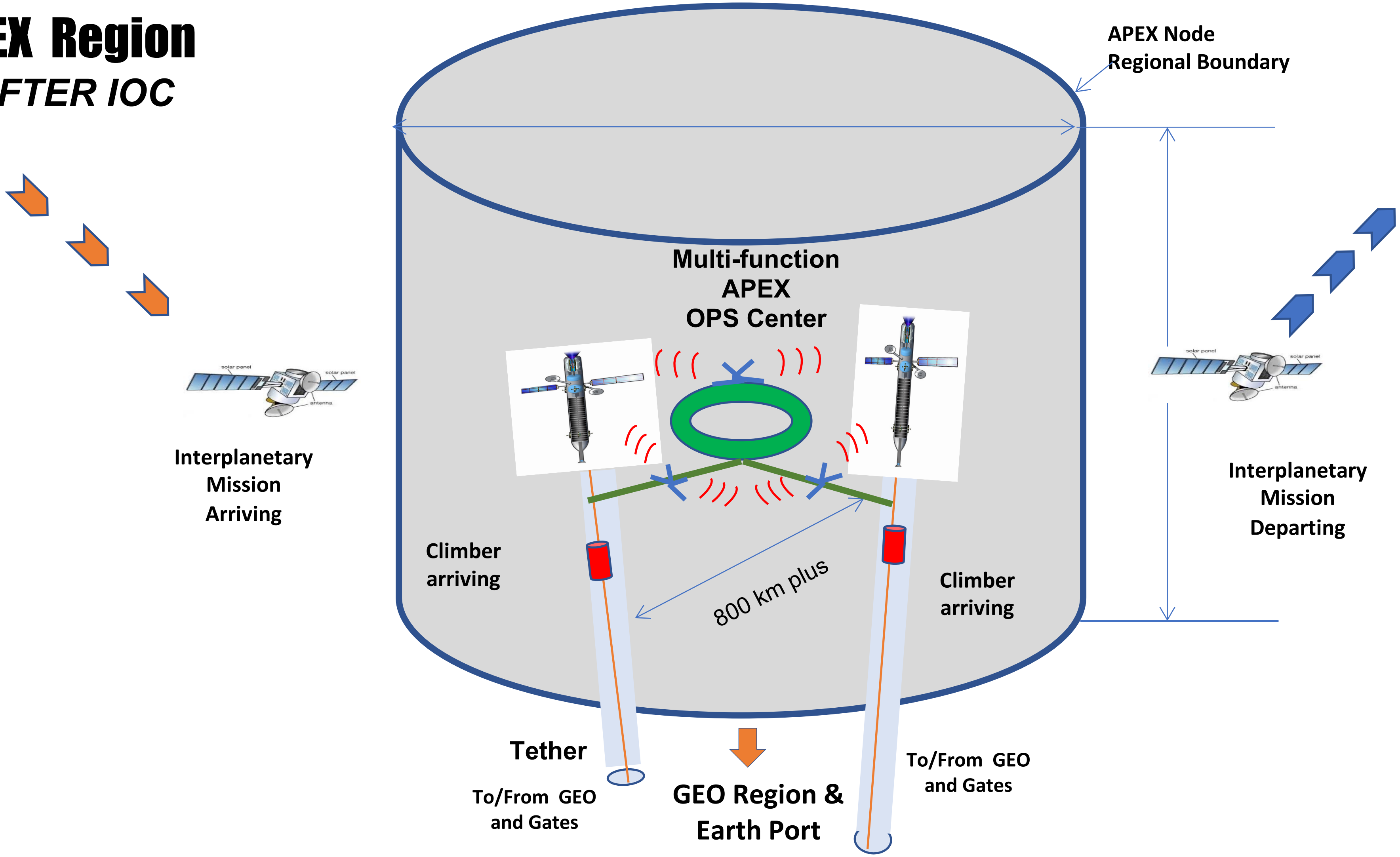
The GEO Region

SPACE ELEVATOR
GEO Region
AFTER IOC



The Apex Region

SPACE ELEVATOR
APEX Region
AFTER IOC



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ISEC Studies

2021	Design Considerations for the Space Elevator Climber-Tether Interface - in progress
2021	Space Elevators are the Green Road to Space
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

Completed studies on www.isec.org in pdf format are free

	Other Study Reports
2019	The Road to the Space Elevator Era - IAA IAA = International Academy of Astronautics (https://iaaspace.org)
2014	Space Elevators: An Assessment of the Technological Feasibility and the Way Forward - IAA
2014	The Space Elevator Construction Concept – Obayashi Corporation (https://www.obayashi.co.jp/en/news/detail/the_space_elevator_construction_concept.html)

Thank you for your time

This is the Transportation story of the 21st Century

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Collaboration is Mandatory

BACKUP