Space Elevator Transportation System
SEATTLE 2018
Documenting the BASELINE

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AGENDA

1. Review Progress during 2017
2. Topic ➔ The Space Elevator Baseline

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BLUF – Bottom Line Up Font
We have a Baseline

- We have a Baseline Space Elevator Transportation System – but it is poorly documented and it is hard to find,
  - Rule # 36 -There is always a baseline;...tho' you may have to look for it.
  - The baseline will change
    - See Arch Note #4(Seek a baseline or 2), Arch Note #12 (2017 Conference), and Arch Note #14 (”Delineation”)

The Year 2017 was a big year. It was so big that it has taken nearly 3/4 of 2018 to get our story straight; and if we could just get people to join with us and our vision; all would be good. Right?

Not really, we need to change or improve a few things and **then** all would be good. Right? Not really, we will need to change or improve a few more things and then all would be good. Right? Well … maybe; but I doubt it. Therefore, I have an announcement!

We should be prepared for a decade of changes; followed by another series of changes; and after that, more changes. So, we need an orderly change approach. An immutable change approach is essential so that all working on the Space Elevator are working on the same thing.

The Main Message

2017 - The year of change

The Galactic Harbour is the unification of Transportation and Enterprise

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

- *GEO Node*
- *Earth Port*
- *Apex Region*
- *Climbers*
- *Tethers*
- *HQ & Ops Center*

Businesses flourish as part of the Space Elevator Enterprise System

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

Catalyzing force

The need to solidify the view into a new plan of action

- In 2017 ➔ The complex inter-relationships of the elevator system AND the future enabled enterprises needed to be resolved; if only to temper apoplexy.

  - Separate systems identified – a Transportation System and an Enterprise System
  - "Separate but not segregated" paradigm to be enforced; cross system awareness avoids a 'bridge to nowhere' outcome.
  - Collaborative involvement with Space Industries and other Space Elevators essential
  - Overall Unifying, Operational View needed … The Galactic Harbour

Overview

The New Message in 2018

- By the middle of this century, we expect to have an operational Space Elevator Transportation System as part of a burgeoning Galactic Harbour

- The International Space Elevator Consortium laid out **seven** basic technology readiness statements that validates 2018 theme: *The Space Elevator Transportation infrastructure is closer than you think.*

- In Support:

*The Chief Architect presented the **seven** point preliminary Technology Readiness Assessment, and connects those **seven** points to the next steps of engineering development for the Space Elevator's Transportation System; the Main Channel.*

We Need a baseline

The Baseline of the Space Elevator is still changing and that is a good thing. (See Architecture Note #4)

Early in 2017, We didn't have one baseline and now we have two; at least we have our Strategic Approach (See Architecture Note #9)

The Strategic Approach

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

We Need a documented baseline

The Space Elevator Transportation system is the core of our vision. The transportation system will provide affordable & reliable access to space.

- We have started the baseline documentation process simply; by lifting information from completed documentation we have in hand.
- Experience shows that building the first baseline is a hit and miss, iterative process; a bootstrap miracle.
- Baselines are built by trial and error mixed with sweat and tears.

We must finish documenting it.

We Need a baseline

The documentation of the Space Elevator Transportation System Baseline.

- The Earth Port Baseline is described thoroughly in ISEC Position Paper # 2015-1; "Design Characteristics of a Space Elevator Earth Port".
- The Headquarters / Primary Operations Center Baseline is described in ISEC Position Paper # 2014-1; "Space Elevator Architecture and Roadmaps"; and in ISEC Position Paper # 2012-1; "Space Elevator Concept of Operations"
- The Apex Anchor and the Geo Node Region Baselines are described thoroughly in ISEC Position Paper # 2017-1; "Design Considerations of a Space Elevator Apex Anchor and GEO Node".
- The Tether Climber Baseline is described thoroughly in ISEC Position Paper # 2013-1; "Design Considerations for Space Elevator Tether Climber".
- The Tether Baseline is described in a number of places. In fact, the Tether is the most described segment of the Transportation System. The Tether Baseline is described in ISEC Position Paper # 2014-1; "Space Elevator Architecture and Roadmaps". The Tether material is the pacing item for the development of the Space Elevator. Currently, there are at least three known 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 its own weight and multiple Climbers

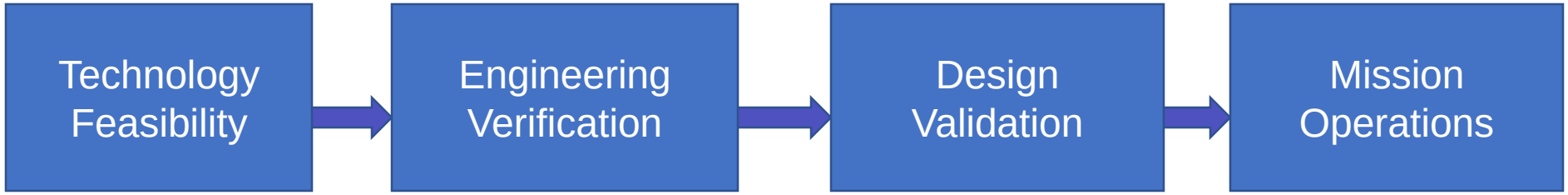
We Need a baseline

The performance of the <u>Space Elevator Transportation System Baseline</u>.

- One HQ/POC
- Two Tethers
- Fourteen Climbers
- One Earth Port - with a Floating Operations Platform and Two Tether Termini
- One Apex Node – with two Apex Anchors.
- One GEO Node Region providing “overhead functional support”
  - ❖ Parking Orbits for test and deployment service craft
  - ❖ Situation Awareness sensing (tbd)
  - ❖ Test data collection and environment data collection support (tbd)
  - ❖ Safety functions (tbd)

Space Elevator Transportation Infrastructure
-- Architecture Engineering 101 --

Stages of “Maturity”

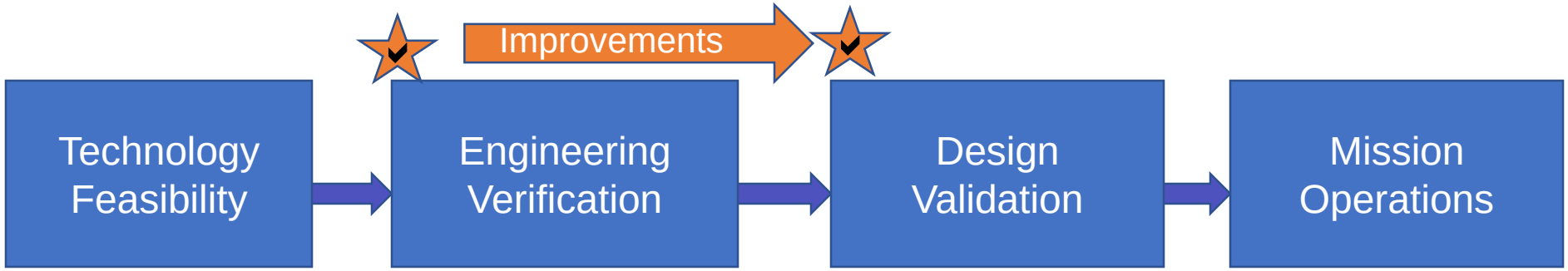


Our Technology Development Strategy
– our Maturity program -

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

Space Elevator Transportation Infrastructure
-- Architecture Engineering 101 --

Baseline Identified



Our Technology Development Strategy
– our Maturity program -

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The Space Elevator Architecture Engineering 101

Next Steps

- Technology Feasibility ➔ Pass
- Engineering Verification ➔ Does it work?
- Design Validation ➔ Does it do its mission?
- "…..its closer than you think!"

At this stage it must "work" to be in our baseline

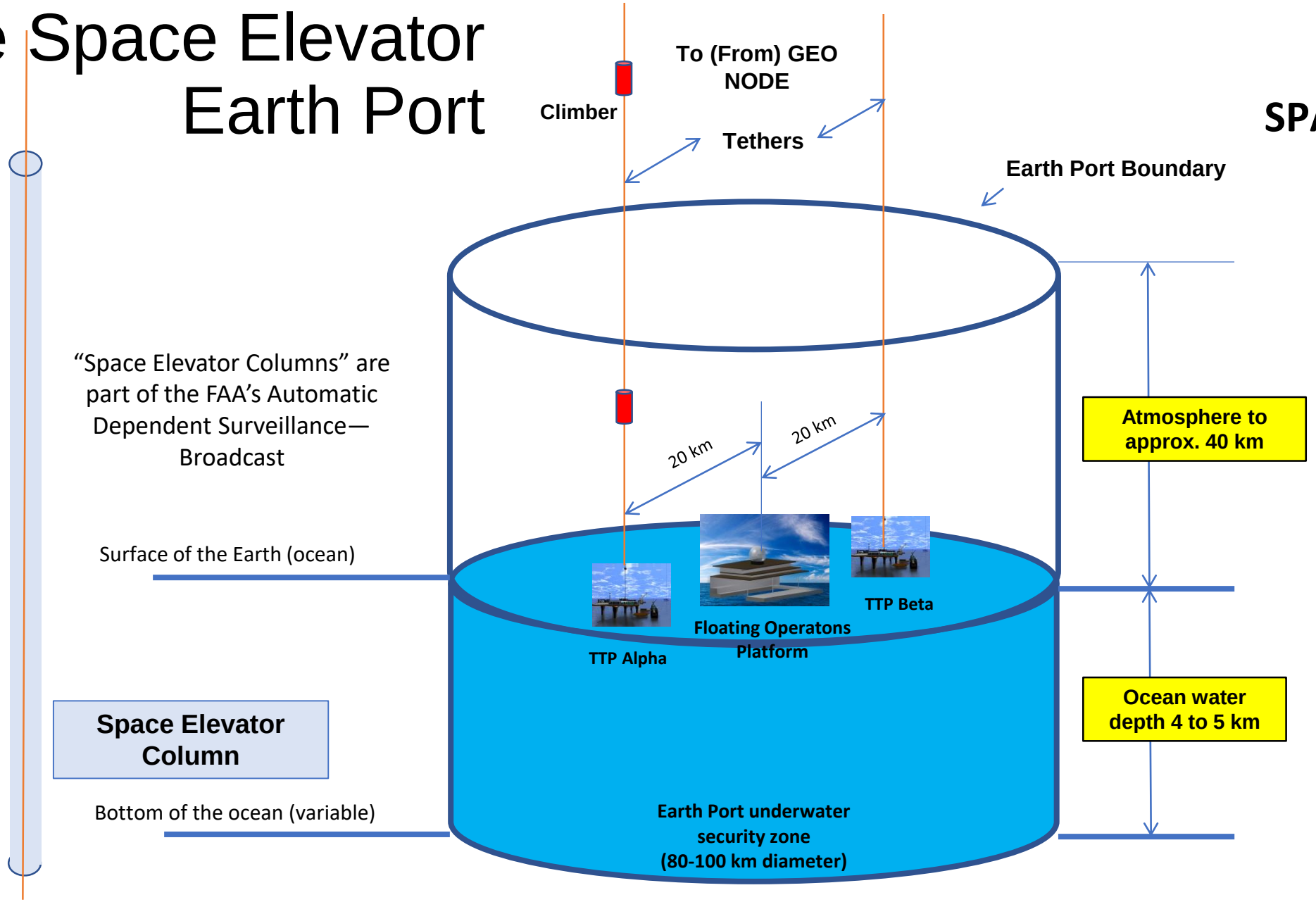
The Baseline

The Space Elevator Transportation system is the core of our vision. The transportation system will provide affordable & reliable access to space.

The Space Elevator Transportation System baseline is made of six segments.

- The Earth Port,
- The Apex Anchor,
- The GEO Node Region,
- The Climber,
- The Tether,
- The Headquarters / Principle Operating Center (HQ/POC).

The Space Elevator Earth Port



SPACE ELEVATOR
EARTH PORT
AT IOC

Key Earth Port Functions

- Horizontal to Vertical Transshipment of the Climber and/or the Payload at the MSSE platform
- Tether Horizontal move management
- RIRO operations
- Human support within the Earth Port
- Payload capture & Movement control (vis the lower altitudes)
- Power provision to the Earth Port

The Space Elevator Earth Port Validation Checklist

Functional Requirements (see ISEC Position Paper 2015-1)

- **Connect “H to V” Transportation Chain (shipping and air cargo)**
- **OGV fleet: tug/barge, hi-speed ferry, long range amphibious and**
- **Service Craft: off-shore service vessels, harbor tugs, patrol craft, helicopters, seaplanes, drones,**
- **“City at Sea” including: cargo handling terminal, shops and storage, communications and control center, marina and crew support facilities, client and visitor services....security**
- **Meteorological and oceanographic monitoring equipment and facilities with wave attenuation system**
- **Three platforms: Floating Operations Platform (FOP), 2 Semi-submersible Tether Terminus Platforms (TTPs)**
- **Earth Port will also have responsibility for tethers and climbers to 40km**

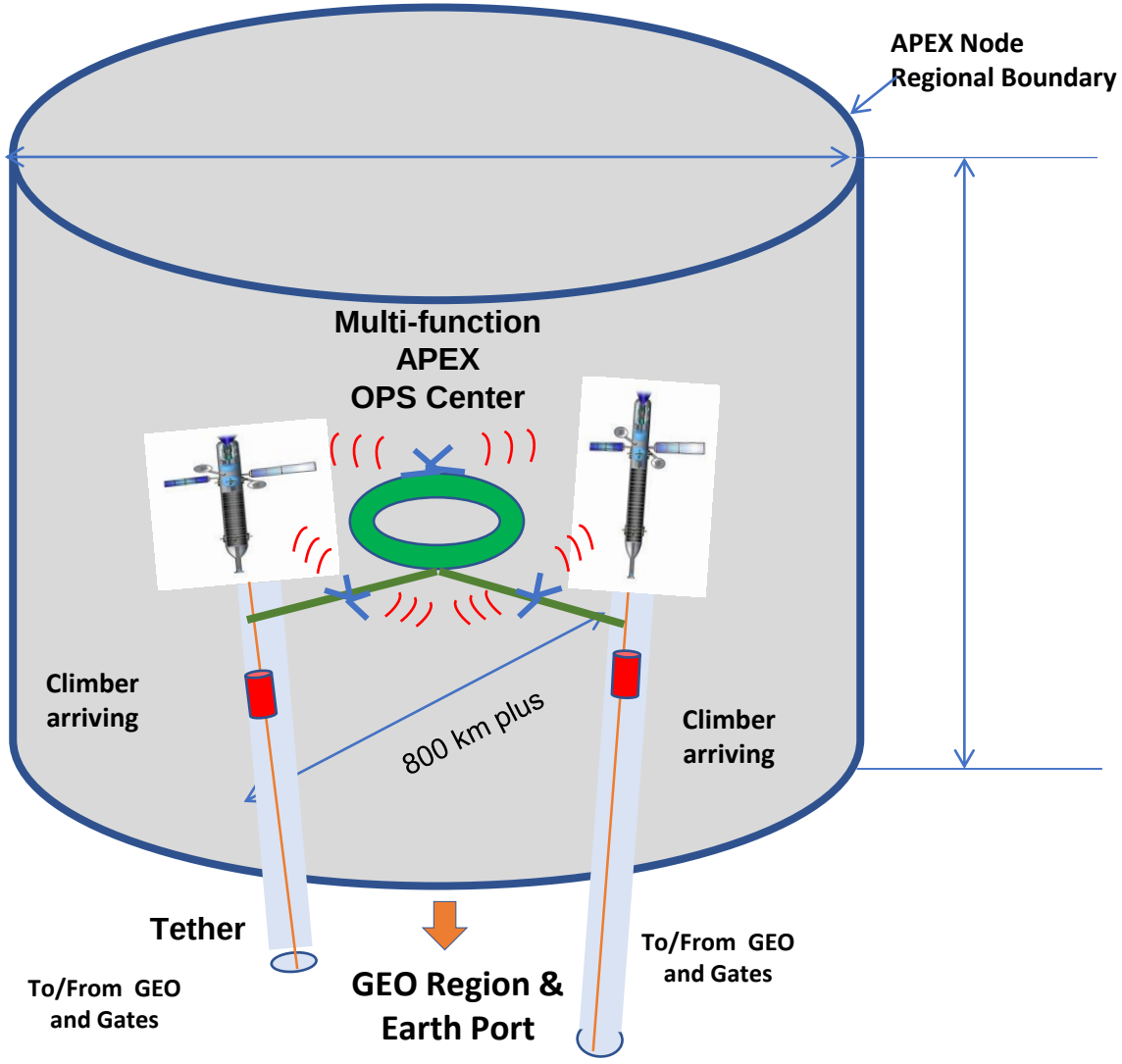
Why isn’t the Multi Stage Space Elevator part of our baseline?

- We are not ready.
- We have no information that the EARTH Port with an MSSE will be an improvement over an EARTH Port without an MSSE. To get to the bottom of that we need to see solutions that resolve Earth Port major functions:

1. Horizontal to Vertical Transshipment of the Climber and/or the Payload at the MSSE platform
2. Tether Horizontal move management
3. RIRO operations
4. Payload capture & Movement control (vis the lower altitudes)
5. Power provision to the Earth Port
6. Human support at MSSE platform

SPACE ELEVATOR
APEX Region
IOC concept

APEX Region
Sensing



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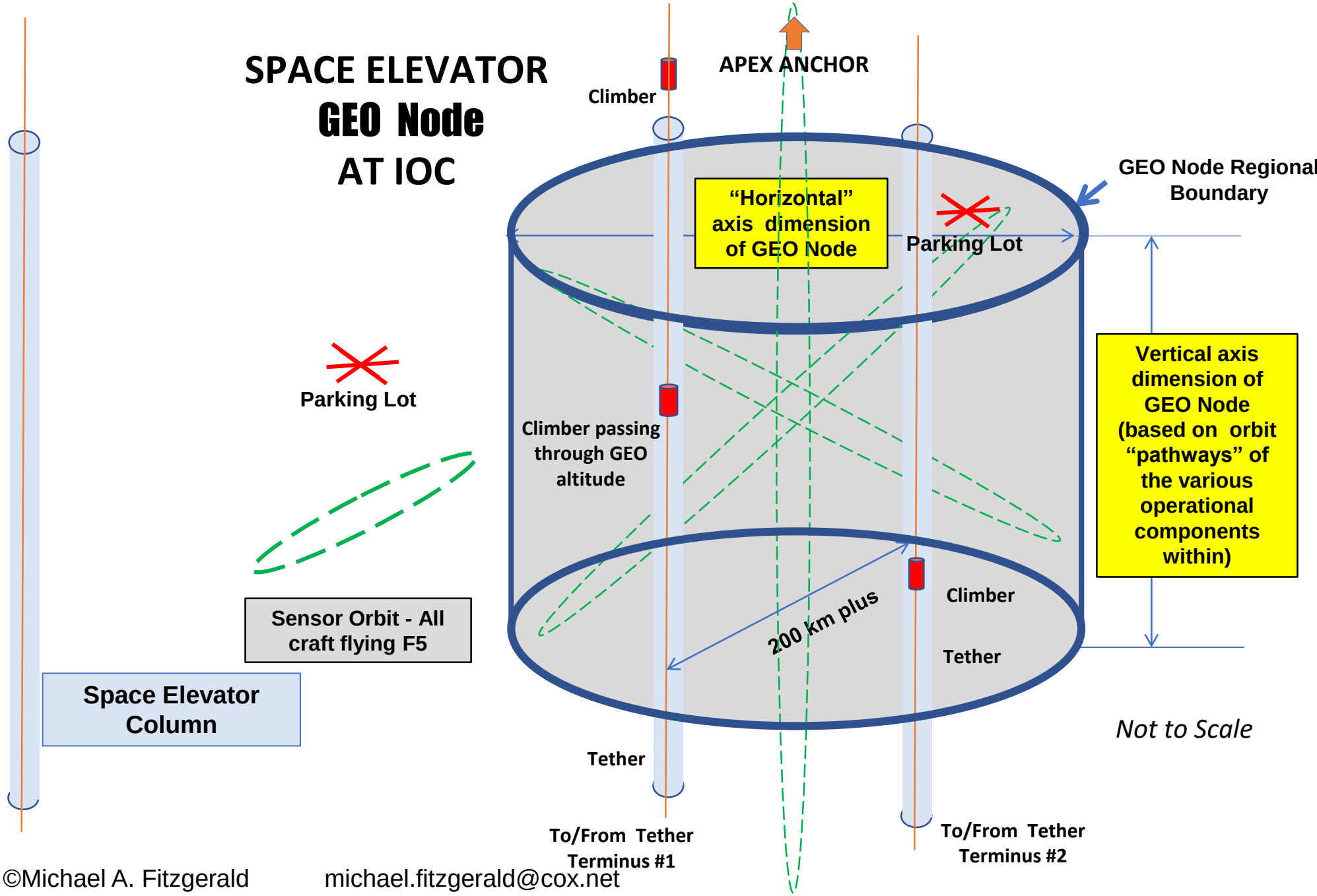
The Apex Anchor

- **Deployment Body Support:** Provide support to full infrastructure during initial deployment of tether. As the total space elevator is derived from the process of deploying tether and Apex Anchor, this segment's function will dominate during deployment and early build-up phases.
- **Stability Support:** Continuous control and stability of the Apex Anchor must be maintained. Concepts for control of the dynamics of the tether are expanding as more people look at the problem. Some elements of tether dynamics control are:
  - **Mass** at the upper end provides inherent stability,
  - **Reel-in and reel-out** will provide forces to the tether that can be used to dampen motion
  - **Motion dampening –**
    - Tether climbers residing at the Apex Anchor, or along the tether, could be leveraged to climb down the tether – thereby putting forces on the tether in a controlled manner to damp out motion.
    - Thrusting in horizontal directions can dampen motion in the total tether.
- **Build-up Support:** The obvious activity is the build-up and strengthening of the tether with additional mass supporting appropriate tether strength requirements. Support from the Apex Anchor will be in the communications, control and acquisition of any of the tether build-up climbers reaching the Apex Anchor. In addition, there will be the task of off-loading and ensuring safety when mass is delivered to the Apex Anchor, whether it be build-up climbers or derelict satellites.
- **Sever Support:** Reaction to the severing of a tether must initiate multiple pre-planned activities. The concept being developed relies upon the belief that the space elevator can survive a sever if it is cut in the lower reaches of space. If the tether is cut at the highest danger zone, 800 km altitude, the remainder of the space elevator will react to the loss of mass and connection force. The belief is that with quick reaction at the GEO Node and the Apex Anchor, the total space elevator above that sever altitude might be saved. This would require many actions in a timely manner such as release of tether from both GEO Node and Apex Anchor as well as motion of tether climbers on the remaining tether. Knowledge of the cut must be almost instantaneous [can be accomplished with today's sensors and communications capabilities], while the support must be pre-planned and almost instantaneous.

SPACE ELEVATOR
GEO Node
AT IOC



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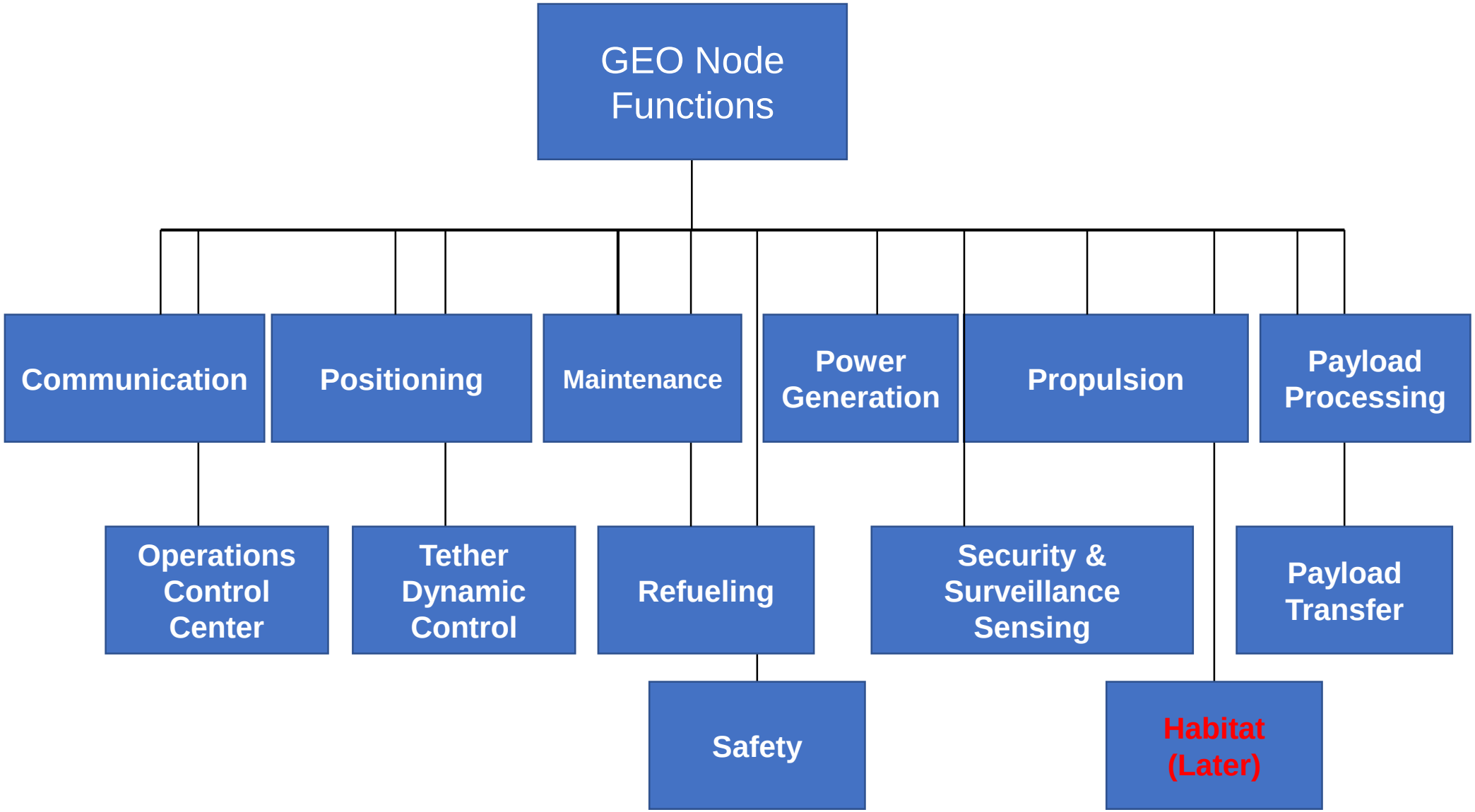

GEO Node Functions
Communication
Positioning
Maintenance
Power Generation
Propulsion
Payload Processing
Operations Control Center
Tether Dynamic Control
Refueling
Security & Surveillance Sensing
Payload Transfer
Safety
Habitat (Later)

HQ / POC Major Functions

- Mission Planning
- Activity Planning and Development
- Mission Control
- Data Transport and Delivery
- Navigation Planning and Analysis
- Spacecraft Planning and Analysis
- Payload Planning and Analysis
- Payload Data Processing
- Archiving and Maintaining the Mission Database
- Systems Engineering, Integration and Test
- Computers and Communications Support
- Developing and Maintaining Software
- Managing Mission Operations
- Financial Management

The HQ/POC Segment

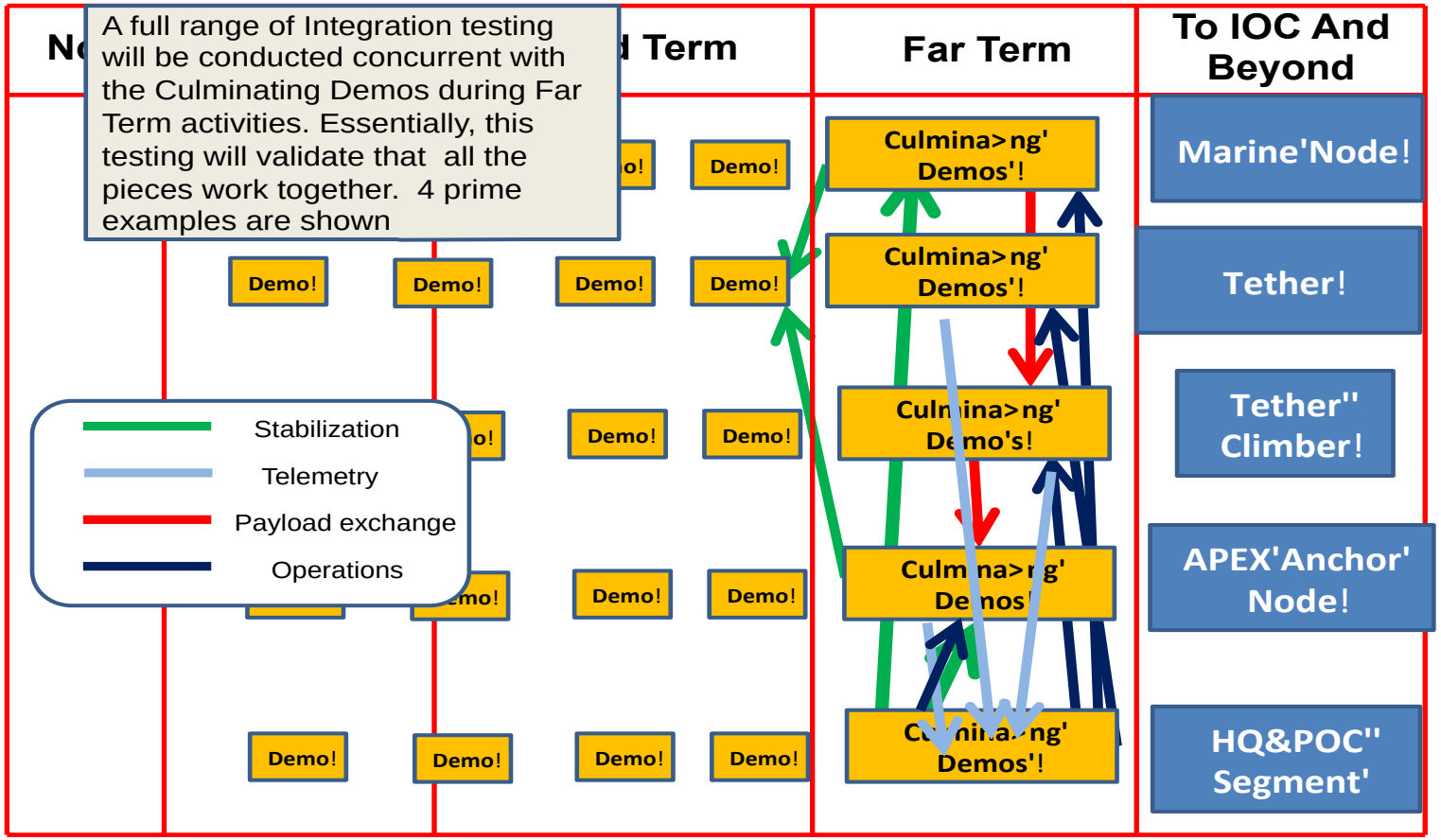
Composed of a number of operations centers

- Primary Operations Center
  - An Ops Center of the Ops Center
  - Overall View of the operating status
- Transportation Operations Center
- Payload (Satellite) Operations Center
- Climber Operations Center
- Tether Operations Center
- GEO Node Operations Center
- Marine Node Operations Center
- (Apex Anchor Operations Center)

Description Each of these centers are amalgams of the needed communications, tracking, forecasting, and monitoring tools. The concept presented is that the Space Elevator Transportation System keeps track of things from product delivery, to the insertion of the satellite into proper orbital position. Positive control of all aspects. The day to day transition approach seemed to be rolling handover – a la flight control centers

Challenge The challenge in this segment is demonstrating how the several centers can share information and notification between and among themselves. A fine software and modeling challenge. Building that operations modeling scheme is the challenge; especially forecasting how such a thing can be upgraded or modified with minimal operations breakdown.

The HQ / POC Pathway



The Tether Segment

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The Tether Segment

The Tether Segment's primary functions.

1. The Tether is Long and Strong
   - Long is 100,000 kilometers
   - Strong is able to support the 100, 000 Km tether itself and a few active climbers.
2. Tether Control
   - Move the tether when needed
   - Dampen movement when needed
3. Tether Motion and Operations are modeled / simulated
   - Predict the need for movement due to any number of factors
4. Tether Deployment including the deployment of 100,000 Km of Tether to Space in a manner to enable ground attachment – at the Earth Port
5. *The Tether is the ribbon that the Tether Climber will grip as it rises toward its destination and as it descends to the Earth Port*
6. Repairable ?

The Climber Segment

- The Climber Baseline is described in ISEC Position Paper # 2013-1; and "Design Considerations for Space Elevator Tether Climbers".
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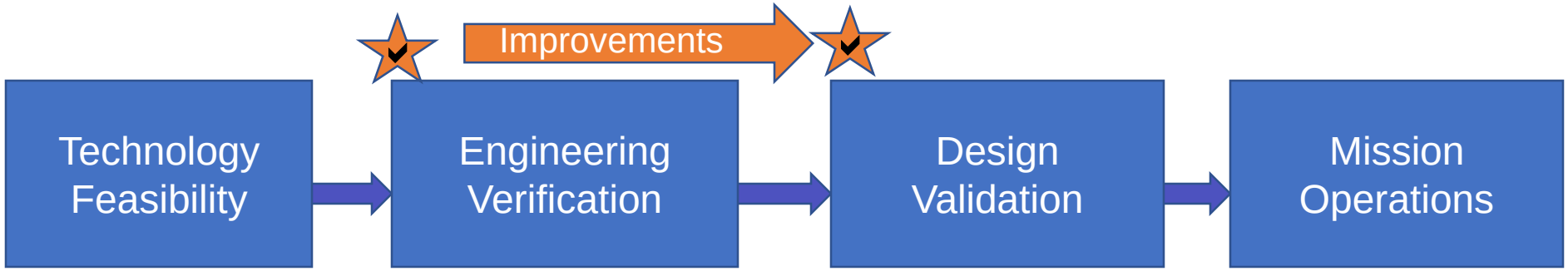
The Climber Segment

The Climber Segment's primary functions.

1. Receive power
   - Solar Power
   - Laser Power
   - Both
2. Cargo Capacity
   - 14 (tbr) Metric tons
3. Grip the Tether
   - Ascend to Apex Anchor
   - Descend to Earth Port
4. Protect the cargo (tbr)
5. Communicate / Determine Position
6. Assess the state of the Tether ?

Space Elevator Transportation Infrastructure
-- Architecture Engineering 101 --

Baseline Identified



Our Technology Development Strategy
– our Maturity program -

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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 approaches 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";

Findings

- The current baseline of the Space Elevator Transportation System is largely complete.
- The documentation is scattered and, in some cases, vague.
- A publication should be developed
- A First Draft should be completed by October; in concert with the IAC announcement of the IAA report *"Road to the Spae Elevator Era".*