IAC-18-D4.3.1

Galactic Harbour Duality -- Enterprise and Infrastructure

Peter Swan* & Michael Fitzgerald**

[a] International Space Elevator Consortium, Paradise Valley, Az, USA dr-swan@cox.net. **International Space Elevator Consortium, Rancho Palos Verdes, Calif. USA. Michael.Fitzgerald@cox.net

Abstract

The Galactic Harbour is a combination of at least two space elevators into a coordinated infrastructure for movement of payloads up and down to/from space and multiple commercial enterprises throughout the regions. One of the principle elements of the International Space Elevator Consortium's (ISEC) action plan towards operational space elevators is to understand its customer utilization. The Galactic Harbour operates continuously, moving customer payloads and support material within Climbers and along Tethers. Climbers rise from the Earth Port toward exit gates at the GEO, or Apex Regions or above. The delivered payloads are the future's new versions of today's operating satellites; and the support material is seen as "spare parts" for payload repair, refueling, and more. The Galactic Harbour will be an area incorporating an Earth Port [on the ocean, with incoming and outgoing ships, helicopters, and airplanes]; stretched up in a cylindrical shape including two tether columns towards an Apex Anchor region. Products [satellites, people, resources, etc.] would enter the Galactic Harbour around the Earth Port and exit at some point along the tether [to LEO, GEO region, Mars, Moon, asteroids, intergalactic, and towards the sun] depending upon where they are released.

1. Introduction: The Galactic Harbour is a transportation infrastructure that moves payloads from the surface of the Earth up to release points along a space elevator tether. As shown in many other documents, there are release points and entry points inside the complex called the Galactic Harbour coming and going from and to many destinations. The concept is basically that the payloads going to space inexpensively would enter the Galactic Harbour at the local "pier" inside the Earth Port, move up the space elevator tether to an exit "pier" and depart for mission destinations. As the tether climber rises on the tether, the energy is increased and may therefore go to further and further desired locations. Some of those are: A Gate for Low Earth Orbit [23,750 km altitude], a Gate for GEO [35,780 km altitude], a Gate for Lunar Orbit [50,960 km altitude], and a Gate for Mars release [57,000 km altitude]. After going to the Apex Anchor and timing the release, the payload can go throughout the entire solar system with a few gravity assists. This entry/exit strategy matches most harbors around the world with entry piers for loading and exit piers for unloading. Figure 1 shows the entry and exit points that are obvious during this phase of development. The transportation aspect of a Galactic Harbour can be defined as continuous operations of the Space Elevator as it transports customer payloads on multiple Space Elevators from the entry

pier to exit pier.

The International Space Elevator Consortium's concept of a Galactic Harbour will enhance understanding of Space Elevator operations[*]. Galactic Harbour is a new term representing multiple independent Space Elevator segments [Earth Port, Tether, Tether Climbers, GEO Node and Apex Anchor] that make up the concept with two co-existing space elevator tethers. A basic concept of this process is that the transportation aspects are parallel with giant ocean or land port facilities while the arena supports commercial enterprises throughout the port. As the Galactic Harbour is vertical, the port operations stretch from the Earth's surface to release points along the tether. Earth and space commercial operations will be conducted along the tether to enable success throughout the regions of interest.

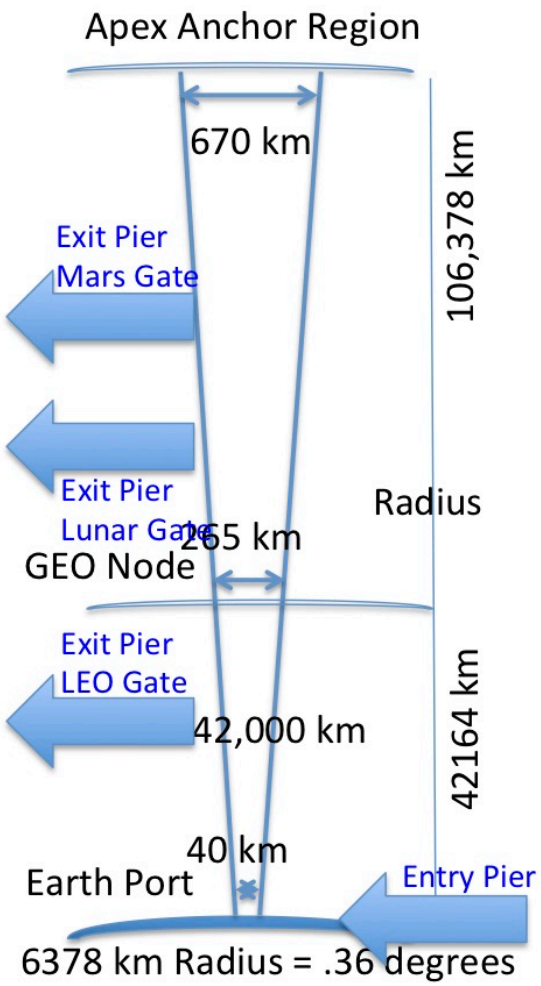
2. Vision: The Galactic Harbour consists of:

- An Earth Port with a complex of platforms performing different functions
- Two tethers going up from Earth Port tether termini
- An Apex Anchor at the far end [100,000 km altitude] of each tether
- Up to seven tether climbers on each tether below GEO [with three climbers beyond GEO going towards Apex Anchor or release point for Mars or the Moon]
- GEO Node region centers – considered as free floating multi-purpose spaceports with multiple functions [such as refueling, servicing, construction, tug boats, power generation, communications, parking, storage, etc.]

The Galactic Harbour will be the area encompassing the Earth Port [covering the ocean where incoming and outgoing ships/helicopters and airplanes operate] and stretches up in a cylindrical shape to include tethers and other aspects outwards towards Apex Anchors. In summary, customer product/payloads [satellites, people, resources, etc.] will enter the Galactic Harbour around the Earth Port and exit someplace up the tether [to LEO, GEO regions, Mars, Moon, asteroids, intergalactic, and towards the sun, dependent upon where it is released]. The "Galactic Harbour" is identified to be the transportation "port" for the total transition from the ocean to release in space. The port would be three dimensional, not surface only. The concept is the payload comes into the Galactic Harbour. It is then processed and released at some pier. The GEO Node is a good example of where a communications payload would be prepared for release, powered up, checked-out, and then released to float towards its assigned slot at GEO. The intra-transportation is very similar to a train operation, movement on rails from one station (Port Pier) to another. The difference is the Galactic Harbour will be up to 100,000 km high for payloads to be released at Apex Anchors. Figure 1 explains the flow of payloads within a Galactic Harbour:

[*] This paper reflects results from one-year studies by ISEC on SE topics. Much of the content is paraphrased from the study activities. [1, 2, 3, 4]

Figure 1, Galactic Harbour



3. Major Segment Breakout and Potential Enterprises: A complete breakout of the major segments can be accomplished when one looks at the recently completed studies by ISEC covering tether climbers [1], Earth Port [2], Apex Anchors [3] and GEO Nodes [3]. [Each can be downloaded at the ISEC site as a pdf]. Each of these major segments will be explained below with potential business enterprises within each region.

3.1 Earth Port: A complex located at the Earth terminus of the tether and has the requirements to support its functions. The volumetric region around each Earth Port includes a Space Elevator column for each tether and the space between multiple tethers when they operate together. The Earth Port Region will include the vertical volume through the atmosphere up to where Space Elevator tether climbers start operations in the vacuum and down to the ocean floor. The potential businesses that represent supporting enterprizing are [both humans and hardware]:

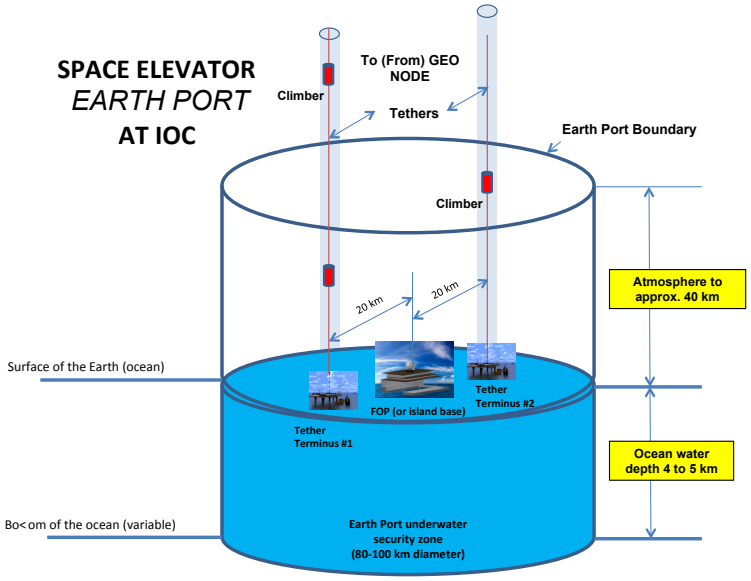


Figure 2, Earth Port with Two Space Elevators

- Transportation to/from the Earth Port with air/sea/land movement
- Operations support across the Earth Port Region
- Energy supply for the total space elevator
- Payload handling, storage, preparation, loading, unloading, and safety of operations
- Hotel, restaurant, entertainment support for Earth Port personnel.
- Communications and Monitoring

3.2 GEO Node and Region: A complex of Space Elevator activities positioned in the Space Elevator GEO Region along the Geosynchronous belt directly above the Earth Port. This Region encompasses all volume swept out by the tether around the Geosynchronous altitude, as well as the orbits of the various support and service spacecraft assigned to the GEO Region.

When two or more Space Elevators are operating together, the region includes each and the volume between elevators. There will be several sub nodes: one for each tether, for a central main operating platform, for each "parking lot," and others. [Note: at the GEO altitude, the GEO Node complexes can maintain their locations naturally within the GEO Region] [For full definition and explanation of GEO Node, see references 3 and 4.]:

- Transportation to/from GEO within the Region - space tug boat concept
- Operations support across the GEO Region
- Energy supply for GEO Region operations
- Payload handling, storage, preparation, loading, unloading, and safety
- Communications and monitoring of status of systems within Region
- Storage, repair, and refueling facilities
- Construction and support of large satellites
- In the future, support for human operations (energy, air, heat, radiation protection, etc.)

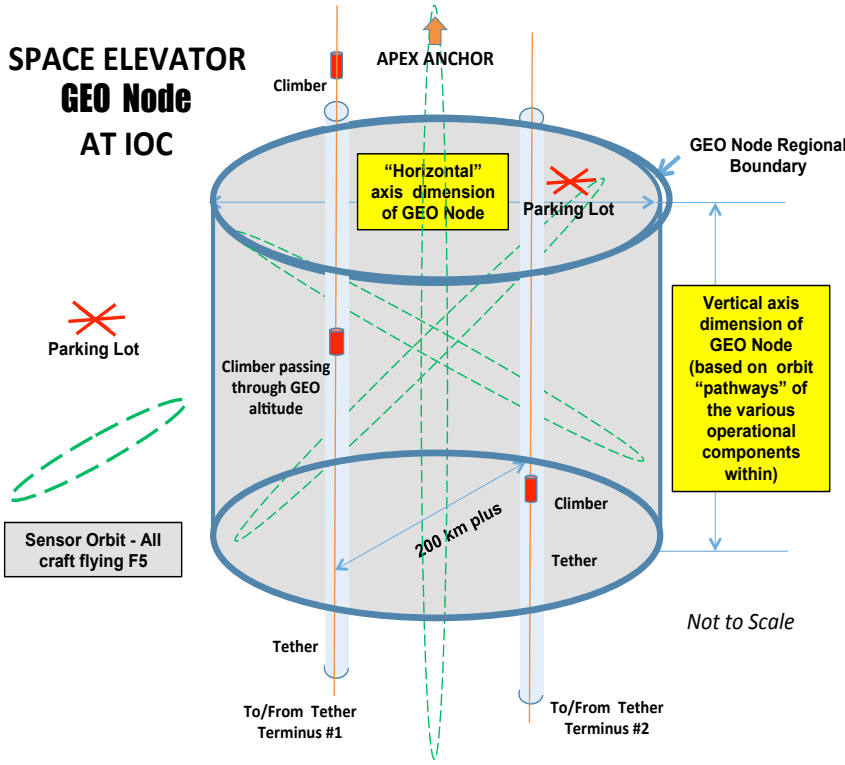


Figure 3, GEO Node Region with Two Space Elevators

3.3 Apex Region: A complex of activity located at the end of the Space Elevator providing counterweight stability for the Space Elevator as large end masses. Attached at the end of the tether will be a complex of Apex Anchor elements such as: reel-in/reel-out capability, thrusters to maintain stability, command and control elements, etc. [Note: nothing stays at that altitude unless attached to a tether] [For full definition and explanation of Apex Anchor, see references 3 and 4.]. The region around the Apex Anchor is defined by the amount of motion expected at the full extension of the tether. The region is the volume swept out by the end of the tether during normal operations. When two or more Space Elevators are operating together, the region spreads to the volume between them.

- Transportation to/from solar system locations with release and capture
- Operations support across the Apex Region
- Energy supply
- Payload handling, storage, preparation, loading, unloading, and safety of
- Communications and Monitoring

4. Unification of Transportation and Enterprise: A clear separation between the transportation revolution and the visionary entrepreneurial enterprises will emerge within a Galactic Harbour. The separation of a Transportation System and Space Elevator Enterprise must be recognized and encouraged during architecture development but then are unified in the coordinated operation of the Galactic Harbour.

Figure 4, Apex Anchor Region with Two Space Elevators

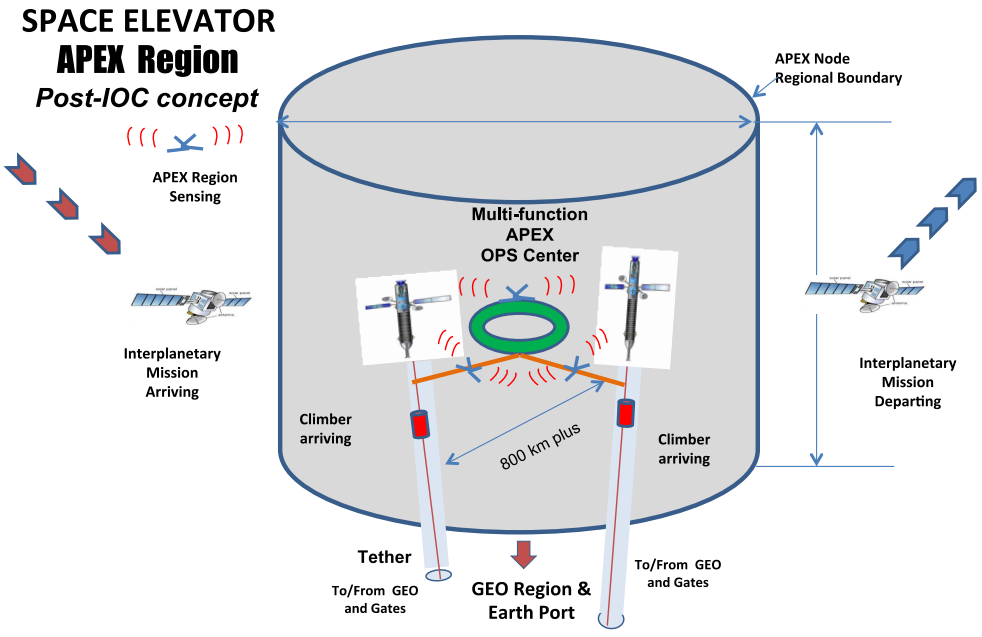
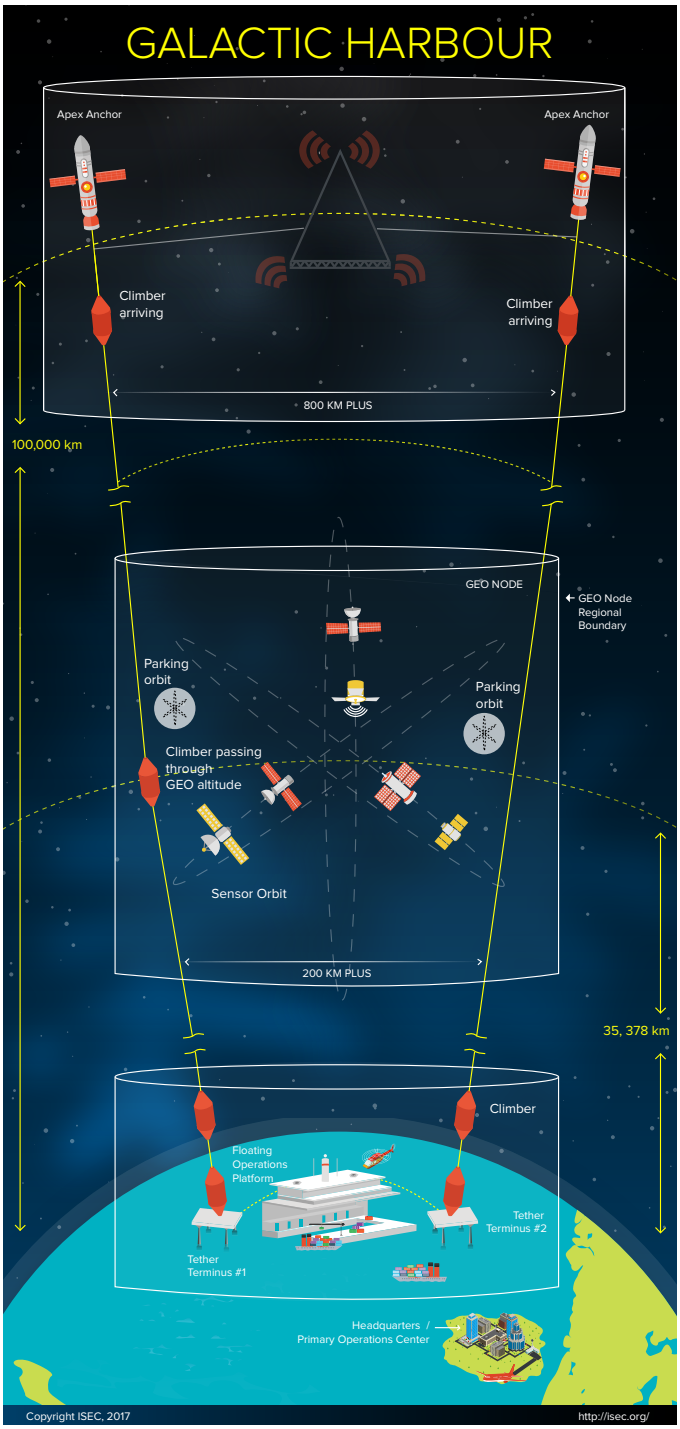


Figure 5, Galactic Harbour



The Galactic Harbour is the unification of Transportation and Enterprise. As payloads start to move throughout the space elevators, a core construction priority will drive businesses that will then lead to expansion beyond traditional functions. One projection is that the GEO Region will entice the construction of large enterprises to support non-traditional space businesses. What one sees now are a magnificent, large commerce and industrial regions in space, supported by this new, revolutionary space access transportation system; an elevator. A needed capability is the generation of power to be projected down to the surface of the Earth from GEO. This Space Based Solar Power will no longer be restricted by huge costs for access to the orbit. Inexpensive delivery of payloads to GEO for construction purposes will lead to inexpensive power with almost zero carbon footprint on the surface of the Earth.

Another mainline purpose will be to provide an inexpensive access to all planets in our solar system (as well as our own Moon) with routine release and capture enabled by the lack of a need for huge rockets and consumption of massive amounts of fuel. As the space elevator is built and deployed, the:

Galactic Harbours will Unify Transportation and Enterprise Throughout the Regions.

5. Conclusions and Recommendations:

When one ties the International Academy of Astronautics three year study to the understanding of a Galactic Harbour, interesting conclusions surface. These are brought forward from the draft study report [5] and support the phenomenal potential for Galactic Harbours.

- *The Earth Port is buildable with today's available technologies and engineering expertise.*
- *The Headquarters and Operations Centers are buildable today.*
- *The tether climber is so similar to a normal satellite design of today that there is no real technological or engineering challenge; except the interface with the tether material. As there is a lack of information of the chosen material for the tether, some engineering must be resolved at a later time.*
- *The GEO Node and GEO Region technologies are understandable and not an issue during development.*
- *The Apex Anchor will be a challenge as its role is key to the building of the space elevator, but not an engineering and technological issue.*
- *However, the tether material is the pacing item for the development of a space elevator. Currently, there are three viable materials that could grow into the needed strong enough and long enough material for a space elevator; carbon nanotubes, boron nitride nanotubes, and continuous growth graphene. The community waits for those materials to mature to the level that can be implemented into a space elevator tether 100,000km long and strong enough to support its own weight plus multiple tether climbers against the pull of gravity. At 100 million metres long, a space elevator tether is a major engineering challenge. Recent investigations explored the possibility of making single crystal graphene by a continuous process using liquid metal. Making this a viable practical manufacturing process will be a significant effort over a period of years and probably many millions of dollars. However such a process would create graphene products for many multi-billion dollar markets on the way to making the tether material. For this reason there is a credible return on investment case for manufacturing the material in practice. This means it is highly possible that continuous single crystal graphene will be manufactured in the coming years and that this material should be considered in any forward thinking about a space elevator tether.*

This could be the story of this century. Reliable, safe, and efficient access to space. This transportation capability is close at hand. Probably within 25 years. Space access without rockets! The Galactic Harbour opens the road, it opens the Heavens; it opens the way. …

There are three recommendations currently being emphasized throughout the space elevator community. Each of these supports the concept of Galactic Harbours:

- *The vision of a Galactic Harbour should be enhanced as a unifying force for the space elevator community.*
- *Increasing the body of knowledge surrounding the Galactic Harbour will lead to a better understanding of the progress of development and identification of necessary actions.*
- *Funding the basic research in higher risk technologies necessary to develop the space elevator is essential and must start with the tether material development and, in parallel, address other critical technologies.*

with the final realization:

The Space Elevator is Closer than you Think!

References

[1] Penny, Robert, Cathy Swan and Peter Swan, Design Considerations for Space Elevator Tether Climbers, International Space Elevator Consortium Study Report, 2014

[2] Hall, Vern, Michael Fitzgerald, Robert Penny, and Peter Swan, Design Considerations for Space Elevator Earth Port, International Space Elevator Consortium Study Report, 2016

[3] Fitzgerald, Michael and Peter Swan, Design Considerations for Space Elevator Apex Anchor and GEO Node, International Space Elevator Consortium Study Report, 2017

[4] Fitzgerald, Michael, Robert Penny, Peter Swan and Cathy Swan, Space Elevator Architecture and Roadmap, International Space Elevator Consortium Study Report, 2015

[5] Swan, Peter, David Raitt, John Knapman, Akira Tsuchida, Michael Fitzgerald, Road to the Space Elevator Era, International Academy of Astronautics, Study Report, April 2019 (draft)