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Space Elevator Transportation System enables many Space Missions

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Abstract: The authors have called for starting the engineering development of a Space Elevator Transportation System. The International Academy of Astronautics made the same call in its 2019 report “Road to the Space Elevator Era.” (Ref 1) In the authors’ case the call is based on engineering readiness. In the IAA report, the call is augmented by a call to support humankind’s needs. The authors seek to merge the obvious: the citation that the Space Elevator is ready for development, and that the Space Elevator is important to humankind. This begins with connecting the various purposes of an Space Elevator (e.g., lift cargo to GEO), and then makes a preliminary correlation of what the it will do. Indeed, full recognition shows that the Space Elevator Transportation System (SETS) is inarguably part of the future space transportation architecture; joining rockets. From the aspect of potential users, the operational Space Elevator Transportation System will provide from essential support to the deployment of Space Based Solar Power, to the delivery of logistics in support of the Martian Settlement, supporting many Cislunar excursions, and more. Our research has shown that, when accumulated, the amount of the cargo delivered by SETS represents the classic requirements for an aggressive movement off-planet. The authors explain the call for such requirement cases with the true spirit of collective collaboration. Further, the research focused on the basic notion of “development” - as in maturity, growth, and accommodation in service to the Space Elevator’s purposes. Research Conclusion: Requirements definition should proceed. Collaboration and coordination are essential to progress toward a viable space infrastructure. Elements of that progress will be the appearance of several new, focused space missions enabled by the Space Elevator. Four such missions are cited.

Introduction: The research reported in this paper was completed by the Chief Architect and the Harbour Master of the International Space Elevator Consortium over the last few years. It is a result of ongoing science and engineering discussions. Most importantly, it is a sincere effort to chronicle the technical considerations within the progress of Space Elevators and the future space Infrastructure they will support. The transformational characteristics of Space Elevators will enable space missions, decrease space access difficulty and costs, ensure environmentally safe operations, and provide strategic economic investments. Joining with the coming advanced rockets in a Dual Space Access Strategy will ensure executing missions only hoped for - until now.

The conclusion of this recent research is that we can start development now! The Modern-Day Space Elevator has evolved from a dream to a definable engineering reality and has moved into the second phase of development (Engineering Validation). This maturation occurred as the limiting factors of the past have been overcome. Building the Space Elevator, as the Green Road to Space, has started! An essential element of the

discussion about being ready and being needed includes the economic investment and growth ... matching the Planet’s needs. Strategic investment in the economic potential of the Space Infrastructure – an infrastructure with a safe and reliable access - provided by the Space Elevator - is essential for Humankind. Development of a permanent space access architecture will be like establishing a new bridge to an island. Development blossoms at both ends of the bridge. Some of the new missions are less obvious than the grand efforts mentioned above. The authors have made a distinct effort to examine other missions; less obvious perhaps, but essential none the less. It touches us all, and our entire future.

The Modern-Day Space Elevator is proposed as part of everything discussed in the last few years because it transforms the approach for development and operations. Space Based Solar Power will be developed, nuclear waste products will be sent off to the Sun, cargo of all sorts will be delivered to GEO headed to enterprises in the Region. The cargo will be hustled around these orbital Region by tugs of all sizes, and large cargo craft destined to various stops within the solar system will be assembled at GEO and/or the Apex

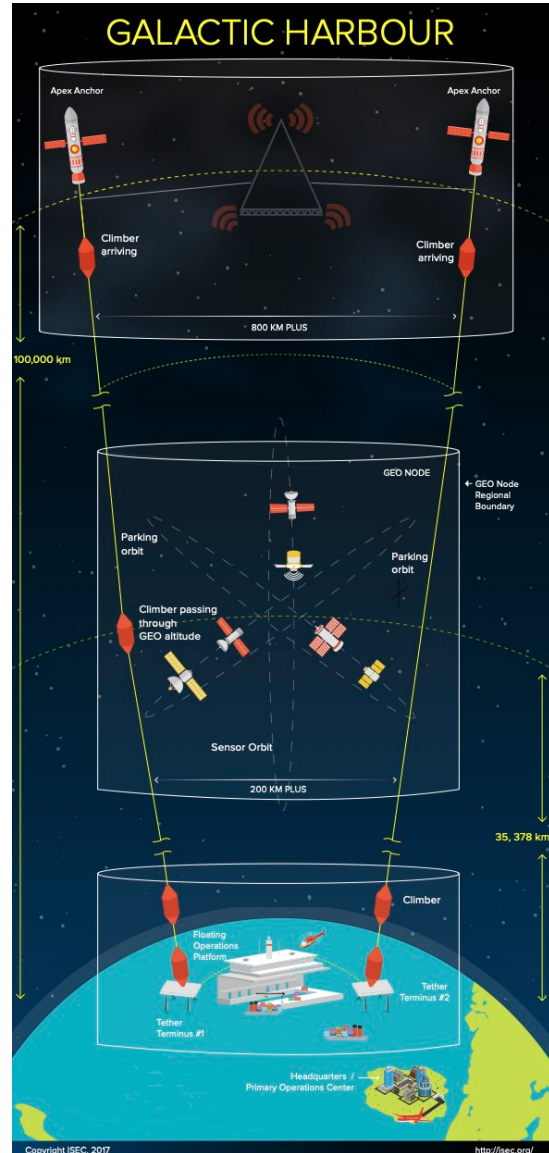
Anchor. It is a remarkable story, and the full texture of that story is recognized by some other missions borne of the Space Elevator. This Galactic Harbour image reflects the active communities to be developed at the Earth Port, the GEO Region and the Apex Anchor.

Figure 1: Galactic Harbour

Missions Enabled by Galactic Harbours: One of the conclusions from this research is: We can initiate the development of space elevators today! The two International Academy of Astronautics study reports (Ref 1 & 2) (and resulting four year studies) have lowered the risk and identified the status of each of the segments of the infrastructure development. The Galactic Harbours will be able to lift 170,000 tonnes to GEO per year once fully operational. (Ref 3) This capability will fully support the goals of the envisioned Space Based Solar Power constellations, and substantially satisfy global base electrical power needs by mid-century. The concept of mining operations on other planets and along the asteroid belt is more reasonably achievable via the Galactic Harbours. The network of Galactic Harbours will enable much more and that is the theme of this discussion.

Further, the International Space Elevator Consortium also completed a study that shows that the Space Elevator is the Green Road to Space (Ref 4) that has zero emissions inside the atmosphere and they do not leave residual components in Low Earth Orbit as debris. Some of the critical missions that were identified in this last report were:

- Early operations of Space Based Solar Power (SBSP) will mitigate climate change effects significantly using rockets alone.
- Special mining operations at several planets within the solar system are enabled by the three Galactic Harbours envisioned. (Six Space Elevators are based at these three Galactic Harbours around the globe).
- Disposal of thousands of tonnes of nuclear waste will be enabled – by delivery to the Sun. The material will be lifted up the Elevator to the Apex, and then released from the Apex to solar destruction.



Galactic Harbours are ready for Engineering Development: The concept of space infrastructures has been gaining interest lately to ensure that the “big picture” is pursued vs. all the parts. Space in general is now fully recognized as the essential venue for economic, environmental, and diplomatic progress in the 21st Century. But it is no longer just an important initiative. It is mandatory, and even urgent. We, who know, are burdened by this; it is our unique version of “noblesse oblige.” The burden is to build it and protect it; and to do so now! It is not a Commercial Space thing, or Civil Space thing, or a Space Force thing. It is a Humankind thing. It is time for stronger justifications and space infrastructures enabling continuous operations via routine access to space. From a technical perspective, it is time to offer some motivations

beyond those identified so far. These “motivations” come from the Galactic Harbour architectural layout:

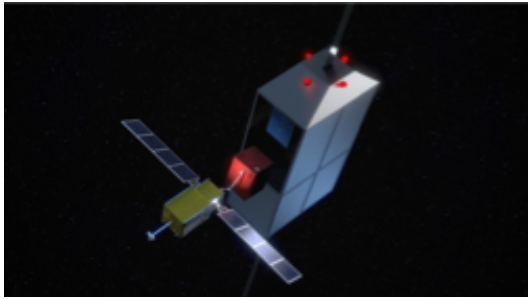


Figure 2: GEO Tug off-loading cargo

- The main elements of the Space Elevator based Infrastructure can be built, beginning now. Testing and design efforts must start, now.
 - The Space Elevator Transportation System, the core element of the infrastructure, will deliver cargo to space-based enterprises, AND provide for daily dispatch of cargo craft to operational locations across the solar system. 30,000 tonnes of cargo delivered yearly. Daily flights dispatched across the solar system during the formative early years. This will grow to 170,000 tonnes per year to GEO and beyond when fully matured.
 - The Space Elevator based Infrastructure will logistically support every major space mission of the 21st Century going to GEO and beyond.
 - Space Based Solar Power demands for mass to GEO are huge but can be enabled with Space Elevators!
 - The Moon Colony can be fully supported
 - Enterprises along the GEO belt can be fully logistically supported, and more enterprises will flourish.
 - The Space Elevator based Infrastructure, will help eliminate the planet’s major environmental issues such as global warming by placing solar power collection satellites at GEO earlier than expected.
 - The Space Elevator Institute (SEI) will provide studied guidance for further engineering enhancements to the Space Infrastructure: Studies to improve flight missions departing from the Space Elevator’s Apex, citations to enhance the overall environmental “greenness” of the infrastructure, and “Imagineering” solutions for destinations and purposes not yet contemplated.
 - The workforce and educational development cannot be underplayed. This adventure foresees a strong connection between success and the individuals that contribute. The infrastructure engineering development and the Space Elevator Institute research need people. This connection must be actively strengthened. The individuals must be educated & trained beyond the current state. Too much education and too may technical may not be enough.
 - Some worry about the ultimate cost of such huge capabilities. That cost argument is the wrong view! Rather, we should comprehend the value and importance of the 21st Century Space Infrastructure and how it enables so much.
- Missions Enabled by an operating Space Elevator Transportation System: Several of the missions for the permanent space transportation infrastructure have been discussed such as Space Based Solar Power and the support to the movement off-planet. However, there are several that have not been discussed out in the space community. Several of these would fall into the following concepts.
1. The Logistics Transshipment Mission: Simply stated, the Logistics Transshipment Mission manages the Galactic Harbour’s cargo delivery service, the final delivery of the cargo to customers. It starts with identification and tracking from the initial loading at a customer’s production facility, tracks it through its transportation history, stores the cargo until the enterprise customer requires the cargo, and then delivers as the customer requests at its destination. (Ref 4.)
 - The Logistics Transshipment Mission is an essential mission. It is as essential as any Amazon Fulfillment Center (here on Earth) is essential to Amazon and to Amazon’s customers.
 - The space logistics transshipment activity is envisioned to be spread across the Galactic Harbour. It will operate as an extension of the worldwide intermodal transportation system.

- It will be in close contact with the Earth Port's Access City, and the Operations Center on the Earth Port's Floating Operations Platform. It also will be in collaboration/coordination with the various enterprises in the GEO Region and Apex Anchor.
 - A key point – the new situational awareness mission (see below) will be very interested in cargo arrival and its final delivery. The Logistics Transshipment Mission “knows” and will maintain positive control of all cargo delivered by the GEO Climber into the Regions.
2. The Rescue Mission: Prepare for, store for immediate release (in the GEO Region and the Apex Anchor), and provide emergency response times appropriate for crisis. This would include vehicles to replace damaged capsules, power to replace failed sources, oxygen (and other supplies) for critical shortages, and medical assistance as needed.
- In the current issue of the National Space Society's magazine ad Astra (NSS ad Astra Q2 2022) (Ref 5) John F. Kross solemnly and respectfully discusses the history of deadly tragedies in space. John reached back and ponders over the deaths of the Russian cosmonauts on Soyuz 11, and the near tragedy of Apollo 13. He then projected that space is a risky place and events like these are more likely to occur because the number of flights will grow over the coming decades.
 - A Rescue capable mission center with a variety of standby unmanned “vehicles” should be established at the SETS's Apex Anchor Flight Operations Center. (Ref #'s 6 and 7) It is a must and could even be christened as station 13/11; in honor of Apollo 13 and Soyuz 11.
 - The 13/11 First Responder station at the APEX Anchor could have an important and special rescue module carried by departing craft of any mass to reach problem sites on the Moon or Mars or anywhere our imagination takes us, or anywhere trouble finds, us. Assembly of rescue components and powerful rocket motors would be accomplished at the Apex Anchor; essentially beyond Earth's gravity, thus ensuring rapid response from pre-positioned equipment
- to anywhere in the solar system with daily and routine releases of high velocity.
- Storage of Rescue Mission components at GEO and Apex Anchor increases probability of rescue success since assembly at these two locations beats the rocket equation and enables responsive daily releases to trouble spots.
3. The (Extended) Situational Awareness Mission: This new and necessary mission envisions a Galactic Harbour operations center working closely with the Situational Awareness authorities regarding who/what is in each of the Regions (Earth Port, GEO and Apex Anchor), who/what is approaching the Regions, and keeping track of all those items - including debris and space detritus that might be wandering by and through the Regions. In addition, monitoring all of the objects inside the designated region of concern must be continuous with forecasting of motion to ensure no conjunctions, including the tether from Earth Port to Apex Anchor (Ref 5)
- It has happened to all of us. We all get a little lost sometimes, but I sure would hate to get lost in the GEO Region. Hundreds of kilometers in all dimensions makes the Region a big place; and this big place will be filled with all sorts of enterprises. The Galactic Harbour operations center must work closely with the Situational Awareness authorities regarding who is in each of the Regions, who is approaching, while keeping track of all those items of debris and space detritus that might be wandering by and through the Region. A Big Job!
 - This mission execution is aided by the fact that the GEO Region is Earth centric – spinning in concert with the Earth's rotation. For instance, objects within the Region can be categorized by their orbital components and whether these components reveal whether the objects will stay within the Region; or not. The situational awareness coverage of the Apex Anchor is included in this mission. The Flight Operations at the Apex Anchor will be a busy complex and must constantly deal with departing and

- approaching spacecraft traveling at incredible speeds.
- Objects entering or departing the Regions could be dangerous to commercial operations. Given that, the Galactic Harbour Operations Center, and the other Space Operations Centers must step up and maintain thorough situational awareness of “Outer Space” within and near the GEO and APEX Anchor Regions. A new mission, indeed.
4. The Explore the Solar System Mission: This mission leads to Transformational Release of Scientific Payloads from the Apex Anchor – Any Size, Every Day, Anywhere in the Solar System. Two main strengths enable these claims of revolutionary Scientific Payloads. The first is the ability to raise massive cargo against the Earth’s gravity while being friendly to our environment. The beauty of Space Elevators is that they raise massive cargo with electricity [hence – “the Green Road to Space”]. The second operational capability is that it can release scientific spacecraft each day towards solar system bodies with great velocity (minimum 7.76 km/sec).
- To set the stage, research within Arizona State University has one example which explains the new conundrum quite well. Traditional launches to Mars are 8-month trips and are separated by 26-month windows until the next opportunity. Currently, delivery to the surface of Mars is about 1 percent of the mass on the pad on Earth. When looking at releases from Space Elevator Apex Anchors (at 100,000 km altitude) the release towards Mars can be every day. In addition, it can send massive amounts of cargo and has a spectrum of travel times – the shortest is a normal release from the Apex Anchor of roughly 61 days. This capability embodies the idea of logistics “on time delivery.” (Ref 3)
 - If Pluto is a planet; it will complete its first post discovery orbit in the year 2178. Amazing, isn’t it! Pluto has completed one third of its orbit around the Sun in the last 70 years.
 - The James Webb Space Telescope provided images suggesting the galaxy imaged was “alive” billions of years ago.
 - This only suggests that we have a lot of exploring to do. It also reminds us that the Space Elevator Transportation System provides unique competencies for the young explorers in today’s fourth grade.
 - Those young minds can begin thinking today about the Solar System they will need to know about when they reach middle age. Where are the special minerals? How do we get there? And how do we get back? How do the unseen gravity forces affect our flights to and from these new discoveries?
 - Imagine how difficult it would have been to explore the USA, if every town and every road was in constant motion. Travel in space is like that. That is the exploration challenge of the 21st century, and only daily, coordinated, flights from the APEX Anchor Flight Operations Center makes these pathfinding discovery flights affordable, repeatable, or even possible. (Ref 6)
- Conclusion: This research was good exercise for those of us working on the start of the Space Elevator’s engineering development. There are more missions to be enabled. There are many that have not even been imagined. Some will be 100% robotic and some will be executed by a required human expert. The Space Elevator Galactic Harbour journey of transformation, invention, and reinvention is going to be exciting. It is now our children’s century – the 21st Century. It needs infrastructure improvements brought forward to suit this century.

Research Summary:

Space Elevator Transportation System (SETS) has Started Development

The Space Elevator Transportation System (SETS) is inarguably part of the future space transportation architecture; joining advanced rockets. The Modern-Day Space Elevator has evolved from a dream to a scientific reality and has moved into the second phase of development (Engineering Validation). The conclusion of this recent research is that we can do it now! The Space Elevator, as the green road to space, has started!

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