Space Elevators as a Transformational Logistics Infrastructure for the Moon

Peter Swan, Ph.D. President, International Space Elevator Consortium

Abstract: Research has shown how a Permanent Space Infrastructure would enable massive movement of cargo to GEO and beyond in a safe, environmentally friendly, inexpensive, daily and routine way – thus transforming the approach for humanity to escape Earth's gravity. Dreams will come true when you can lift 30,000 tonnes to GEO and beyond each year – at initial operational capability (170,000 at full operational capability). This transformation of lunar logistics support will be similar to moving from small boats crossing a large river to a permanent infrastructure – a bridge. This transformation results from inherent Space Elevator strengths: 1) daily, routinely, safely, inexpensively, 2) transforming the economics towards an infrastructure with access to more valuable, lucrative, stable and reliable investments. 3) massive movement (Initial Operational Capability at 30,000 tonnes/yr and Full Operational Capability 170,000 tonnes/yr), 4) high velocity release (starting at 7.76 km/sec at an altitude of 100,000 kms) enables rapid transits to the Moon (14 hours), 5) a Green Road to Space ensures environmentally neutral operations, 6) elimination of rocket fairing design limitations, and 7) assembly at the Top of the Gravity Well.

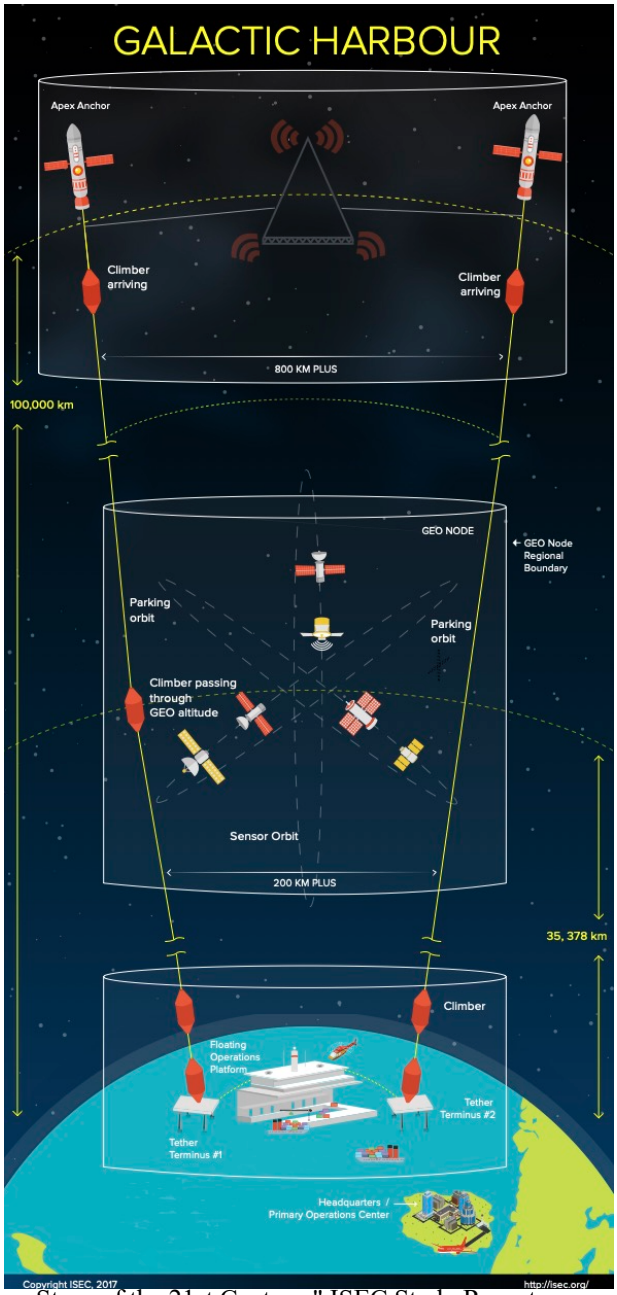

Figure 1: Galactic Harbour (two Space Elevators per)

1.0 Introduction:

The International Space Elevator Consortium (ISEC) and the Arizona State University (ASU) conducted several years of research on the release characteristics of Space Elevators with respect to interplanetary and CisLunar missions.[1] The key discovery from this research has been presented in many papers and is summarized with Figure 2 (Significant Strengths of Space Elevators). These three realizations change the way

[1] Swan, P, Swan C, Fitzgerald, M., Peet, M, Torla, J, Hall, V., "Space Elevators are the Transportation Story of the 21st Century," ISEC Study Report, www.lulu.com, 2020.

researchers look at the strengths of Space Elevators as they change the paradigm of space travel to one of routine, daily, massive movement of cargo and environmentally friendly. Daily releases change the concept of going to Mars from once every 26 months to daily while enabling trips as fast as 61 days. When the students at ASU looked at the trip to the Moon from the top of the Space Elevator, the Apex Anchor, they discovered it was only 14 hours to reach the Lunar region; while requiring rocket motors to slow down as the space systems were moving rapidly at that point. Research into orbits and trajectories accomplished over the last five years has been focused upon Mars and Jupiter as well as several other planets. However, their research was applied to the CisLunar arena to help understand the meaning of their results. From this research, and other ISEC studies and activities, the realization surfaced that the Space Elevator will transform the concept of transportation for space access. These characteristics are explained in the next section, but the importance of these concepts must be pointed out to ensure appreciation of the changes:

> *Payloads (satellites with rocket motors) released from the Apex Anchor will travel faster, release daily, and move more mass than possible by rockets – all while ascending the tether as the Green Road to Space (no burning of rocket fuel in our atmosphere – all electric tether climbers).*

2.0 Transformational Characteristics:

Space access will become similar to moving from small boats across a big river to a bridge moving traffic daily, routinely, safely, inexpensively, and with little environmental impact. This permanent transportation infrastructure of space elevators will enable future missions with their great need to move cargo:

- Daily, routinely, safely, inexpensively
- Transforming the economics towards an infrastructure with access to more valuable, lucrative, stable and reliable investments.
- Massive movement (Initial Operational Capability (IOC) at 30,000 tonnes/yr and Full Operational Capability (FOC) 170,000 tonnes/yr)
- High velocity (starting at 7.76 km/sec at 100,000 altitude enables rapid transits to the Moon, Mars and beyond)
- As a Green Road to Space, it ensures environmentally neutral operations
- Without rocket fairing design limitations
- Assembly at the Top of the Gravity Well

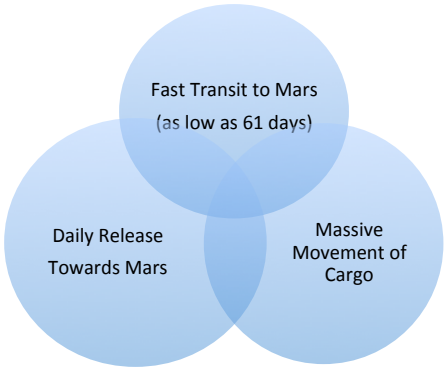

Figure 2: Strengths of Space Elevators

Each of these transformational characteristics stands on it own. For this support to the Moon Village Association, this paper will focus upon three items: routine, massive movement, and assembly at the top of the gravity well.

2.1 *Daily, routinely, safely, inexpensively*: When building a transportation infrastructure, it must be permanent to ensure longevity, responsiveness to customers, and acceptable to the customers. Space Elevators, when operational, will have those basic characteristics:

- Daily lift operations – Space Elevators are currently planning on one lift per day of roughly 14 tonnes with seven tether climbers continuously on each.
- Routine operations – the ability to schedule and depend upon "on time delivery" characteristics of permanent infrastructures will change the way organizations plan on supporting mission to GEO and beyond. Can you imagine scheduling pizza delivery to the lunar surface while ensuring on time delivery of mission critical equipment.
- Safe operations – Space Elevators will be extremely safe with the ability to climb the tethers similar to a tractor or train car. Can you image "guaranteed" delivery of important logistics as needed?
- Inexpensively – The initial cost of the Space Elevator will be no more expensive that the cost of installing a large bridge (and cheaper than the bridge between Denmark and Sweden). This time it will be going straight up to become the bridge to space. The funding profile is remarkable, but the return on this strategic investment is huge over time. A bridge to space with inexpensive lifting will open up the solar system and the CisLunar arena.

2.2 *Massive movement:* This characteristic is the obvious strength that most users need. Massive delivery to the location of choice will enable dreamers such as Mr. Musk, Moon Village supporters, space solar power requirements, and routine historic missions enhanced by this unique capability. The growth of mass delivered to GEO and beyond by Space Elevators has been studied for the last 20 years and the results have been consistent between the ISEC, the International Academy of Astronautics, and most researchers covering the topic. The capability starts with 14 tonnes of payload to GEO lifted off each day (with 7 day trip to GEO then 7 more to an Apex Anchor). This is multiplied by six as the competition develops Space Elevators in our three oceans leading to over 30,000 tonnes per year to GEO and beyond. As this commercial venture expands to meet customer demands, Space Elevators will grow to a more capable design with major redundancies for human travel. This capability would be 70 tonnes per Space Elevator per day times six times 365 days results in close to 170,000 tonnes per year. The chart with this growth pattern is shown in Figure 3.

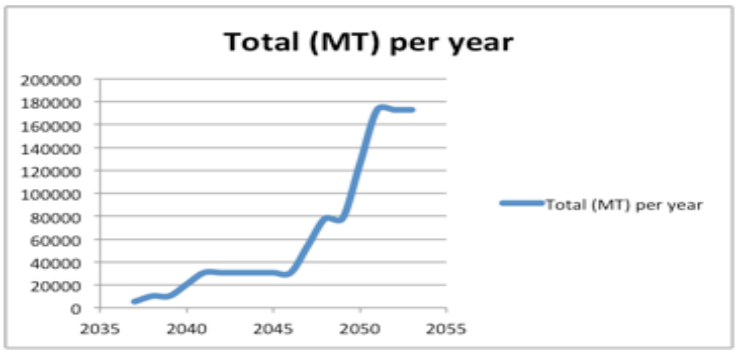

Figure 3: Mass Growth

2.3 *Assembly at the Top of the Gravity Well*: This characteristic is a surprising one that has only recently been understood and explained. The concept is simple – have a "train station" at the Apex Anchor, 100,000

km in altitude. The concept lends itself to phenomenal strengths that are NOT achievable by rockets because this is a location above the gravity well and can access anywhere in the solar system rapidly (release is at 7.76 km/sec). The concept includes the ability to raise any amount of mass (14 tonne parts – later 70 tonne components) to this train station and assemble any size space system. In other words, planetary scientists will not be restricted by mass for their future missions; plus, the cost is miniscule compared to today's mission costs. They can have multiple payloads teamed with multiple rockets to go anywhere. When thinking about CisLunar support, the secret is that replacement parts, safety components, lifesaving facilities can all be only 14 hours away. In addition, having these Apex Anchors in sight of the lunar region allows them to conduct situational awareness continuously.

2.4 *Vision*: The vision of this whole permanent space access infrastructure – which includes two Space Elevators inside multiple Galactic Harbours – is:

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

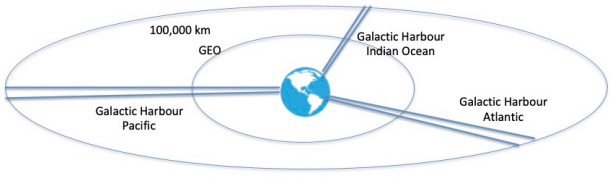

Figure 4, Galactic Harbour Vision

3.0 Conclusions and Recommendations: During the research over the last few years, it has become clear that the access to space requires a strategy of Dual Space Access Architecture to ensure the strengths of both are leveraged for the phenomenal missions being planned. Rockets will be the principle mover of humans for the foreseeable future; while Space Elevators leverage theirs characteristics to move heavy cargo daily. Two things are important to keep in mind with this remarkable concept of Dual Space Access Architecture:

1. The Space Elevator community admires the remarkable progress being implemented within the rocket arena. Reusability, reliability, and redundancy with significant increase in launch pace are all remarkable. However, we must remember that the shortfalls of the basic concept associated with the rocket equation allows only 4% of pad mass to reach LEO, 2% to GEO or lunar insertion, with only 0.5% to any surface (Mars or Moon). The new strengths of rockets are remarkable; however, the rocket equation can not be beaten.
2. The Space Elevator permanent space access infrastructure is called the Green Road to Space because it raises payloads with electricity and does not leave debris behind – 70% of the tether climber is payload while the other 30% is reusable.

With these two realizations, the combining of the capabilities to fulfill future missions such as support to the Lunar Village, delivery of 3,000,000 tonnes to GEO for space solar power missions, delivery of 1,000,000 tonnes to Mars to support human settlements, and all the historic missions that will be expanded as they have "easier"

access to GEO. This Dual Space Access Strategy leverages the strengths of both capabilities to raise payloads to orbit and beyond – including the lunar surface. Indeed, Space Elevators, supporting the Moon Village, will be remarkable in that they will be:

- Transformational in how things get to space and support operations
- Dual Space Access Architecture will leverage the strengths of rockets and Space Elevators
- Green: lifts payloads with electricity and enables Space Solar Power satellites to GEO with a timely schedule
- Closer – as Space Elevators have entered engineering development
- An economic boom as regions open up for commerce because of their routine, daily, and massive lift capabilities.
- Assembly at the top of the gravity well will allow storage, repair, assembly, and timely release of large space systems for any mission, including Astronaut rescue.

References

Eddy, et.al., "Space Elevators are the Green Road to Space," ISEC Report, Lulu Publishers, April 2021. www.isec.org

Ishikawa, Yoji, The Space Elevator Construction Concept, Obayashi Corporation, IAC-13-D4.3.6.

Swan, P., Raitt, Swan, Penny, Knapman. International Academy of Astronautics Study Report, Space Elevators: An Assessment of the Technological Feasibility and the Way Forward, Virginia Edition Publishing Company, Science Deck (2013) ISBN-13: 978-2917761311

Swan, P, Swan C, Fitzgerald, M., Peet, M, Torla, J, Hall, V., "Space Elevators are the Transportation Story of the 21st Century," ISEC Study Report, www.lulu.com, 2020. www.isec.org

Swan, P. "Dual Space Access Strategy Minimizes the Rocket Equation," Space Renaissance International 3rd World Congress 2021 – Congress Theses, Final Resolution and Papers. Pg 254-255.