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Dual Space Access: An Evolutionary Step Towards Humankind's Movement Off-Planet

Jerry K. Eddy, Peter A. Swan***

**International Space Elevator Consortium, Phoenix Arizona, jerry.eddy@isec.org*

***International Space Elevator Consortium, Phoenix Arizona, dr-swan@cox.net*

Abstract: The cooperation of a Space Elevator transportation system (three pairs of elevators in each of the three major oceans) with the largest currently planned rockets is examined. A comparison of using rockets and/or Space Elevators is examined for several important projects. Many projects were studied in a recent study done by The International Space Elevator Consortium (ISEC) entitled "Space Elevators: The Green Road to Space."[1] In addition, it addressed how rockets and Space Elevators can work together to accomplish projects which are not only helpful to the environment but cannot be done by either one alone. It also shows how the settlements planned for the Moon and Mars can be supplied so they can flourish much quicker and safer using the Space Elevator system in conjunction with advanced rockets. Current research is analyzing the impact of implementation of this Dual Space Access Architecture.

1.0 Introduction: When we look at the Moon and remember the space flights, we forget how extremely difficult it was to accomplish, both in energy and design complexity. Tsiolkovsky's remarkable rocket equation consumes so much mass to achieve orbit that, historically, we have been restricted as to what we can deliver. The statistics of rocket delivey to the surface of the Moon and Mars is less than 1% of their mass at lift-off. Now that we have decided to go back to the Moon and on to Mars in a combined international, governmental and commercial effort of great magnitude, we need to expand our vision of how it should be done. The establishment of a more robust infrastructure with reusable rockets and a permanent transportation (Space Elevator) infrastructure must be developed. In this article, we will discuss the strengths and weaknesses of the components of this combined architecture with the purpose of placing mission equipment and people where they need to go and when they need to be there. The multiple destinations, complexity of orbits, magnitude of each transition to orbit, and infrequent launches currently means that the difficulty of fulfilling these efforts is a monumental "reach" with rockets alone. Expanding space access architectures to include Space Elevators will enable robust movement off-planet. This combined robust infrastructure will enable the National Space Society's Mission of: "People living and working in thriving communities beyond the Earth, and the use of the vast resources of space for the dramatic betterment of humanity."[2]

The International Space Elevator Consortium (ISEC) completed a study last year (where for the first time) it was assumed that the Space Elevator permanent space access transportation infrastructure was developed and three pairs of elevators, or Galactic Harbors, existed in each of the three major oceans (see Figure 1). The study was entitled "The Green Road to Space"[3] and examined a number of projects that would be enabled by a Space Elevator transportation system. Each of these projects were examined in some detail; space based solar power, solar sunshades, lunar mining for He-3, and high-level nuclear waste disposal. Recently ISEC initiated a new study called Dual Space Access Architecture to be completed by the fall of 2023. The idea is to show how rockets and Galactic Harbors can work together as a team to open up space and enable the projects studied in the "The Green Road to Space" along with a large number of additional projects. The layout and additional projects will be expanded upon in the later half of this paper.

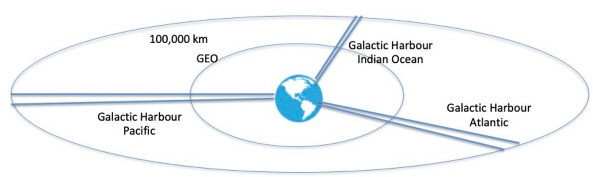

Figure 1, Galactic Harbour Vision

1.1 Initiating the ISEC Study: During discussions for this study, the leadership considered the strengths of rocket launches along with their

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[1] Eddy, et.al., "Space Elevators are the Green Road to Space," ISEC Report, Lulu Publishers, April 2021.

[2] National Space Society, website, 25 Aug 2022.

[3] Eddy, et.al., "Space Elevators are the Green Road to Space," ISEC Report, Lulu Publishers, April 2021.

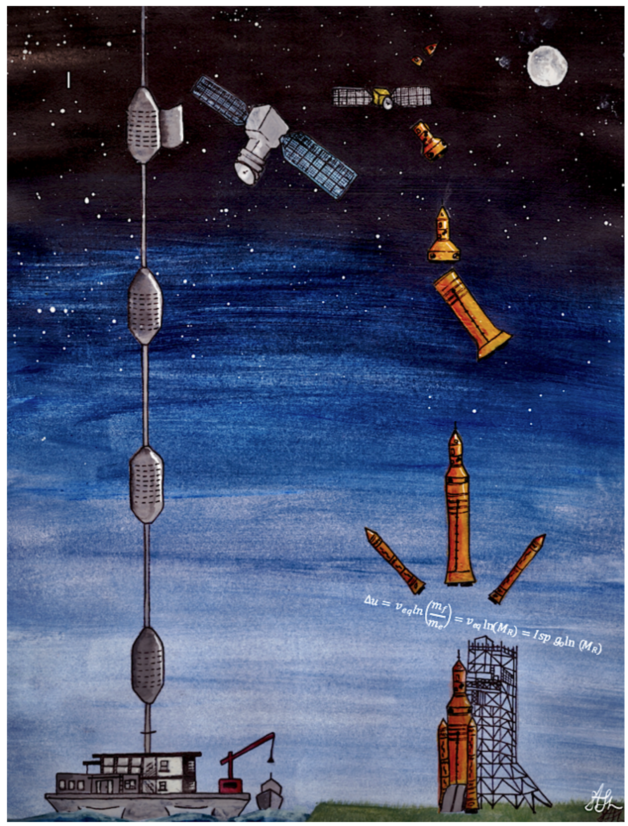
limitations. We recognize there are three principle strengths: 1) rockets are successful today and great strides are forecast for the future, 2) reaching virtually any orbit, and, 3) rapid movement through radiation belts for people enables flights to the Moon and Mars. In this study, we will also examine the strengths of a permanent infrastructure with daily, routine, environmentally friendly and inexpensive attributes. These Space Elevator strengths will be compared to the difficulties of executing a Space Elevator developmental program. Space Elevators will not be ready for initial human migration off-planet for two decades. However, once colonies are established on the Moon and Mars using rockets, Space Elevators will enable their robust growth by moving massive cargo, inexpensively, environmentally friendly, and routinely.

We believe Space Elevators will be the transportation story of the 21st century. Space Elevator Galactic Harbours will become an essential part of the global and interplanetary transportation infrastructure. In addition, as shown by our last study report, the Space Elevator is the "Green Road to Space," enabling massive movement of cargo without damaging the Earth's environment. In the community of off-planet movement with NASA's newest move to put boots on the Moon by 2024, Space Elevators must be considered in the discussions for follow-up activities to grow Lunar villages. The key here is that daily, green, routine, inexpensive, massive movement of payloads to GEO and released from various locations along the Space Elevator tether will allow high speed launches towards other bodies in our solar system. This study starts discussions about the strengths Space Elevators have for supplying activities such as: factories, mining, distributing GEO satellites and other activities that can be more easily accomplished in a weightless environment.

2.0 Dual Space Access Architecture: The reality is when humanity decides to conduct off planet activities, there will be a tremendous need for logistical support, movement of manufactured goods as well as transporting people [especially at low cost and routine/daily]. The question on ISEC's table is: how can the strengths of the Space Elevator enable missions of all types, while having little or no environmental effect on our planet? We believe that not only can it do this, but it also allows activities in space that will improve Earth's environment. This study hopes to show how daily liftoffs on Space Elevators enables the visions of many while ensuring that the Earth's environment is protected.

2.1 A Combined Architecture: The concept is that overlapping strengths reduce shortfalls. The strengths of this Compatible Space Access Architecture will enable human migration off-planet robustly, safely and with very little impact on the Earth's environment. Space delivery can become as routine as Fed-Ex, Amazon, and DHL are today. When customers insist upon having "just in time" delivery, a permanent infrastructure is essential. One significant conclusion is that using the strengths of both parts of this architecture enables so much more than the individual parts.

Figure 2: Dual Space Access
(Amelia Stanton Image)



Strengths of Rockets: Three principle strengths are inherent in rocket operations: 1) they are very successful today, 2) rockets are reaching multiple orbits, and, 3) rapid movement through radiation belts for people is achievable. This historic approach of reaching orbit with rockets has led to remarkable missions. Their safety level is high and the ability to repeat is well known. Customers demand their satellites be placed in specific orbits in order to fulfill their mission needs - from low Earth orbit with high inclinations to unique constellations of satellites for communications. Medium Earth orbits require more energy and specific location insertions to ensure that navigation signals are able to span the globe. These unique orbits require specific timing (launch windows) and insertion vectors to match orbital characteristics. Rockets are very good at fulfilling a variety of customer requests -- about 100 times per year. Multiple launches per year by each separate launch vehicle is routine; but, matching launch locations and mission orbits requires serious planning and execution.

Another series of strengths arise from the need to apply desired forces using small rockets integrated within spacecraft. These propulsion devices accomplish many parts of the missions: Spacecraft pointing, stabilizing a spinning spacecraft, transition between orbits (departure and matching), interplanetary insertion with correction burns, rendezvous with other satellites or locations in orbit, deceleration into orbits around planets or moons, landing on planetary surfaces, and launching from planetary surfaces. Missions supported by Space Elevators also need these capabilities integrated with rocket engines.

Strengths of Space Elevators: Essentially, Galactic Harbour strengths are the characteristics of permanent transportation infrastructures which lead to daily, routine, environmentally friendly and inexpensive departures towards mission destinations. This inherent capability results from "bridge like" characteristics traveling into outer space. Once a Space Elevator has been installed and upgraded to its initial capability, it will be there for a very long time, similar to roads, bridges or train tracks. Raising cargo from the surface of the ocean to an Apex Anchor (100,000 km as a starting concept) is accomplished with external power – primarily solar energy.

Basic Strengths: In addition to a permanent infrastructure's core strength, the dynamics of Space Elevators enable delivery to optimum locations for satellites, especially the historic geosynchronous altitude around the Earth. These orbital slots are valuable for missions such as space solar power and communications. This region will grow as more and more capability is installed by Space Elevators resulting in opportunities for entrepreneurs. Missions such as spacecraft repair and/or refueling and assembly of larger spacecraft will expand rapidly once the low cost of delivery is developed. Because of their characteristics, Space Elevators deliver payloads to their intended destination without consumption of mass. Essentially, at the Earth Port, the payload is about 70% of the mass and will be raised to its release destination without losing anything. The tether climber remains intact as it is energized from external sources (the Sun) and is reused once it completes its mission(s). In addition, the use of Space Elevators ensures space missions can be initiated without endangering the Earth or its environment. There is no rocket exhaust reacting inside the atmosphere or rocket bodies cluttering up low Earth orbits. We recognize that a permanent infrastructure which raises tether climbers using electricity is inherently Earth friendly while becoming the Green Road to Space.

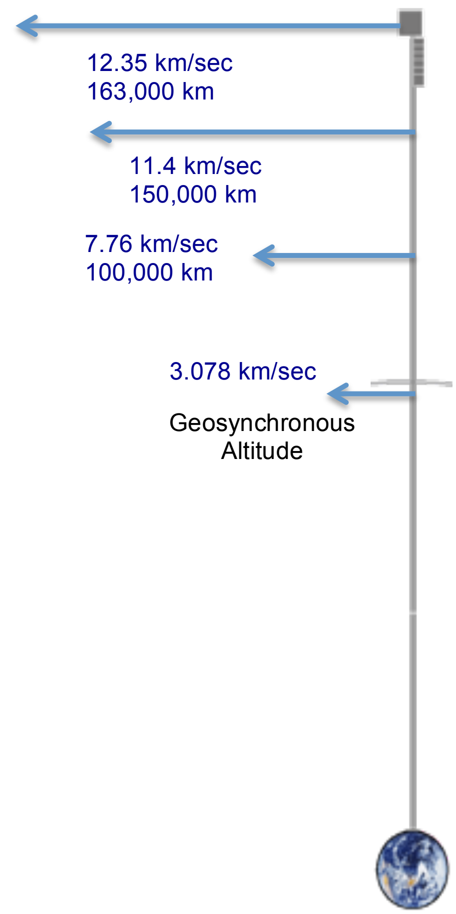


Figure 3: Release Geometries

Interplanetary Strengths: During a joint study by Arizona State University and the International Space Elevator Consortium[4], multiple strengths emerged.

[4] 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.

The design of Space Elevators lends itself to interplanetary missions as it transfers tremendous amounts of energy at release. A 100,000 km Apex Anchor can release towards the Moon and Mars with an amazing inherent velocity (rotation of the Earth with tremendous rotational reach); and, of course, it has huge potential energy due to altitude. The velocity at release from an Apex Anchor is approximately 7.76 km/sec towards mission destinations allowing:

- Fast transit to planets (Can you imagine, as fast as 61 days to Mars with average flight times in the 80 to 120 day region?) (14 hours to Lunar orbit).
- Daily releases of mission cargo towards Mars and other interplanetary locations. (Imagine no 26 month wait for a launch window?) In addition, the study showed that with longer tethers, release velocities increase to enable Solar System escape.
- Massive amounts of cargo towards mission destinations. (5,000 tonnes per year for the first Space Elevator operations with releases growing to 170,000 tonnes per year for a six Space Elevator mature infrastructure)

A Promise for Scientists: We feel we have discovered a strength that is revolutionary; but, it is also very simple. With spacecraft assembly at an Apex Anchor, and extending the length of Space Elevators, the opportunities are endless for scientific payloads – any scientific payload mass to any destination in the solar system with daily launches.[5]

3.0 Space Elevators as the Green Road to Space: Space Elevators will be permanent transportation infrastructures with a zero-carbon footprint. The beauty of a permanent space access infrastructure that is Earth friendly is that it can, in addition to lifting massive payloads without pollution, enable missions to help the environment, such as Space Solar Power. A recent ISEC study report shows how Space Elevators enable missions that cannot reasonably be accomplished with rockets; and thus, they can help improve the human condition on Earth. Space Elevators can move millions of tonnes of cargo with timely delivery to multiple destinations without interacting with our atmosphere. Also covered are the "green missions" that are enabled by a Space Elevator architecture; space solar power, Sun-Moon L-1 solar shade and the permanent disposal of high-level nuclear waste. This last example will remove one of the major reasons that many nations have hesitated using nuclear power to satisfy their energy needs. This study assesses the environmental impact from development and operations of Space Elevators. The title of the report reflects the conclusions: "Space Elevators are the Green Road to Space."

4.0 Initiation of ISEC Study entitled Dual Space Access Architecture: The team has been formed with initial discussions across the globe for an 18-month technical study addressing the strengths of this new strategy. The study has been authorized by ISEC to illustrate the tremendous strengths of the Space Elevator and pair them to advanced rockets. This relationship will lead to a joint architecture leveraging the strengths of both approaches for moving people and cargo.

4.1 Background: We envision Space Solar Power missions to save the Earth's environment as well as Missions to Mars and the Moon of incredible size and scope carrying the dreams/visions of many. All of these immense endeavors will need huge amounts of logistical support. This will require a large number of rocket launches with a negative impact on the Earth's environment. The ISEC has always known that operational Space Elevators will have little or no environmental impact and that a number of environmental problems can be solved with cheap reliable access to GEO using electricity to raise the climbers. This study will investigate the strengths of both space access architectures and compare / contrast the strengths and weaknesses of both. In addition, multiple case studies will be incorporated into the report to enable a Dual Space Access Strategy to emerge and mature.

4.2 A Combined Architecture - overlapping strengths reduce shortfalls: The strengths of this compatible space access architecture will enable human migration off-planet robustly and safely. One significant conclusion is that using the strengths of both parts of this architecture enables so much more than the individual parts.

4.3 Outline for Initiation of the ISEC Study: The breakout of the study could follow the following preliminary outline.

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5 Page, William, Peter Swan, "Transformational Release of Scientific Payloads from the Apex Anchor – Any size, Every Day, Anywhere," International Astronautical Congress, Paris, 9/2022.

Chapter 1: Introduction and Summary
Chapter 2: Dreams of Many lead to Visions (each with a mass to GEO and Beyond identified – Elon Musk, Jeff Bezos, National Space Society (L-5 Colony), Lunar Village, Space Solar Power)
Chapter 3: Space Elevator Strengths / Shortfalls Massive Movement, Green Road to Space, Routine and Fast to Mars and beyond, Routine daily, cost effective safe, Not here today, Slow to GEO and Beyond (once released fast)
Chapter 4: Rocket Strengths / Shortfalls Operational today, Rapid transit to LEO/GEO and the Moon, Fast thru radiation, Delivery statistics of cargo (2% of pad mass to GEO)
Chapter 5: Case Study: Space Solar Power
Chapter 6: Case Study: Access for Mars
Chapter 7: Case Study: Lunar Village
Chapter 8: Case Study: L-5 Colony
Chapter 9: Case study: Sun shades to cool Earth
Chapter 10: Case study: Planetary Defense
Chapter 11: Case study: Planetary Sciences
Chapter 12: Case Study: Missions accomplished only by SEs
Chapter 13: Conclusions / Recommendations

4.4 Significant Questions: This ongoing study will be addressing the above case studies; however, as the team progresses, there will be many new topics to add to the research. Several ideas have already been mentioned:

- Lunar He^3 mining or asteroid development and mining.
- Analysis of the importance of each mission with respect to the future of humanity [unique perspective, such as why, how important, and impact on future progress].
- How much mass needs to be delivered from Earth vs. in-situ resources, and when.
- Trade space between the number of rocket launches and support of each event
- Trade space when operations of a permanent transportation infrastructure reaches Initial Operational Capability and then Full Operational Capability
- Graphical representation of the two space access methodologies comparing tonnes delivered over time with understanding of delivery statistics and impact upon the environment

5.0 Vision of the Future – On to Mars: If the Mars access strategy has two components, you end up with a much stronger position having both rocket architectures of the future and permanent Space Elevator infrastructures supporting movement off-planet. Assessing the previous discussions showing strengths and weaknesses, the logical conclusion is that there should be a concerted effort to ensure development towards a combined space access architecture. Some basic realizations are: (1) rockets should be emphasized for people movement, (2) rockets have tremendous strengths for LEO/MEO destinations, (3) Space Elevators should be leveraged for GEO and beyond, and (4) Space Elevators should be leveraged to deliver massive cargo, equipment, and supplies for GEO, Lunar and interplanetary missions. These factors highlight that developmental planning must be initiated in the very near future for both advanced rockets and Space Elevators. As one who was involved in the interplanetary study by ASU and ISEC, I recognize the strengths and weaknesses of both architectures.

Rockets to Open up the Moon and
Mars with Space Elevators to supply
and grow the settlements.

6.0 Conclusion: Fifty plus years after Apollo, the human race has decided to create a permanent presence on the Moon, in space, and on Mars. Our vision should be similar to the original statement in this paper: three Galactic Harbours, with two Space Elevators each, moving 170,000 tonnes a year to GEO and beyond. Space Elevators are the Green Road to Space where they enable humanity's most important missions by moving massive tonnage to GEO and beyond. In addition, it is important to dream big and deliver Space Elevators of the future. ISEC feels:

"The Space Elevator story is still being written. The Apex Anchor is where the Space Elevator meets the Shoreline of Outer-Space and Where the Transportation Story of the 21st Century meets the Final Frontier."

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