Space Elevators: Introduction to This Special Issue

DAVID RAITT Chief Historian, International Space Elevator Consortium, Piet Heinlaan 12, 2341 SJ Oegstgeest, The Netherlands

Email david.raitt@xs4all.nl

DOI https://doi.org/10.59332/jbis-076-07-0222

Following a short description of space elevators and an overview of the various space elevator architectures to date, brief summaries are given of the five papers in this special issue of *JBIS* which show just how far we have come in building a permanent space transportation infrastructure.

Keywords: Space elevators, Architectures, Galactic Harbours, Tether Materials, Tether climbers, Interplanetary Space Travel

1 WHAT IS A SPACE ELEVATOR?

The concept of space elevators should be well understood by now – at least by the scientific and engineering community, science fiction and space buffs, and knowledgeable laypersons. After all, the idea and dream of some form of essentially fixed mode of transport reaching from Earth to the heavens has been around for nigh on 130 years, and has been well-described in the literature, as well as audiovisual media [1]. To briefly recap the basics: a space elevator is analogous to the elevator or lift in a skyscraper or other building which travels up and down on cables, stopping at various floors to let people on and off. In the case of the space elevator, a ground terminal on the Earth's surface is tied to an apex anchor at the high end by an extremely long (100,000 km) cable or tether up which robotic climber cars would ascend to deliver or release cargo at various points to diverse destinations throughout space without the need for rockets. There have been various refinements and modifications over the years to this basic system architecture and its components [2] with the result that such a space elevator, operating within a galactic harbour, would offer certain benefits when compared to noisy, polluting rockets. For instance, space elevators could provide humanity with daily cheap, routine, cost-effective, clean, and virtually risk-free access to pretty much anywhere in the cosmos.

2 GROWTH TO THE EIGHTH ARCHITECTURE

From Tsiolkovsky's abstract imagining of a space elevator (though he did not call it that) in 1895, then Artsutanov's cosmic railway in 1960, Pearson's orbital tower in 1975, the seminal concept of Brad Edwards in 2000 and 2003 which established the baseline for a space elevator, then the first (2009) of two studies undertaken for the International Academy of Astronautics (IAA), the innovative approach by the Obayashi Corporation in Japan in 2011 which refined Edward's ideas, to the second IAA study in 2014 which introduced the concept of a Galactic Harbour – analogous to a sea-going shipping or container harbour/port. This seventh architecture differed significantly from previous studies and work in that instead of a single space elevator, there would be multiple independent space elevator segments offering continuous operations of the space elevator as customer payloads on multiple space elevators are moved from the entry ports to exit ports within the Galactic Harbour (Fig. 1).

The Galactic Harbour is thus seen as the unification of transportation and enterprise, with businesses flourishing as the movement of goods becomes routine. This vision of the Galactic Harbour shows a high degree of maturity into the overall concept, and newer developments have necessitated a re-evaluation of the overall strategy for bringing the space elevator to fruition. Hence the current thinking within the International Space Elevator Consortium (ISEC) community is of a dual or combined architecture (the eighth) comprising both rockets and space elevators to reduce the shortcomings of each by combining the strengths of each. This insight emphasises rockets for the movement of people since they have tremendous support for LEO and MEO destinations; and with space elevators being leveraged for GEO and beyond due to their ability to deliver huge volumes of cargo and equipment to the Moon and Mars rapidly and securely and without waiting for the precise launch windows that rockets have to take into account.

The Galactic Harbour would thus be well-placed to cater for future space access needs. The estimated amounts of material needed (e.g. for Elon Musk's planned colony on Mars; for solar power satellites delivered to GEO or the construction of huge space sunshades; and ESA's proposed Moon Village habitat) are unlikely to be met in the short or even medium term given the current launch capacities of rockets and the number of launches able to be undertaken per day through the atmosphere.

3 PAPERS IN THIS SPECIAL ISSUE

The mission of these five papers in this special issue of *JBIS* then is to have a positive look at the Modern Day Space Elevator and show how we are progressing in its development. Each paper focuses on the latest research and development of and future exciting possibilities for space elevators. Although most of the com-

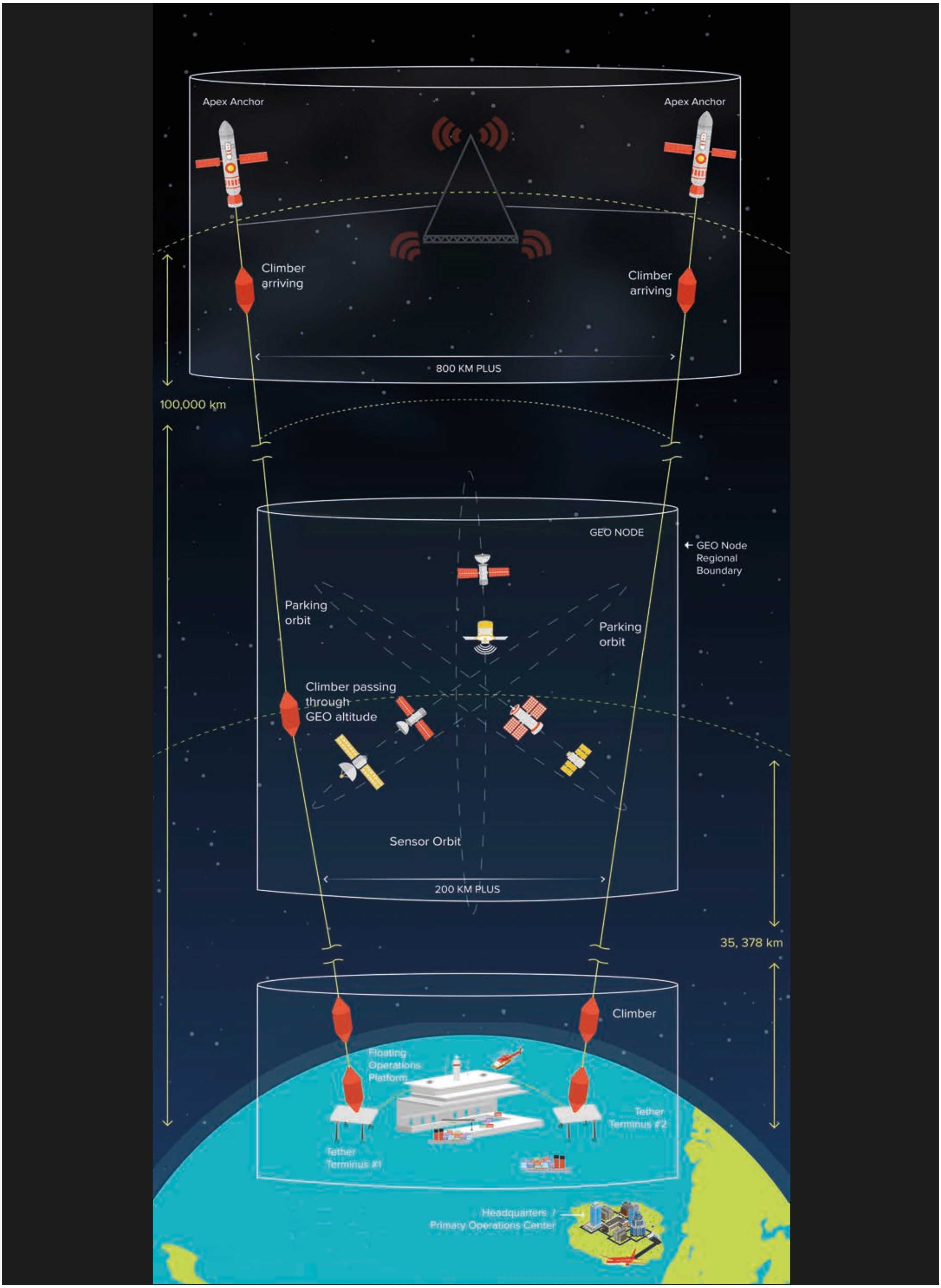

Fig.1 Galactic Harbour Architecture.

ponents of a space elevator system are pretty much already to go, the primary element – the cable or tether – still requires more development work to deliver a suitable material in sufficient lengths. The article by Dennis Wright concentrates on building the space elevator tether which extends way into space and up which climbers pull themselves to deliver their payloads into orbit. To this end, the tether has thus to be not only long enough, but also strong enough to support itself and the climbers upon it at any one time. For some years, carbon nanotubes were considered the material of choice for the tether. Today, however, besides carbon nanotubes two other materials, whose industrial-scale production appears fairly close, are being considered as suitable: single crystal graphene and single crystal hexagonal boron nitride. All three of these materials and their properties are discussed and compared and the options for the construction and design of the tether - either on Earth or in space - are outlined.

In a departure from many other papers about the space elevator, Larry Bartoszek and Dennis Wright focus on the payload design for the space elevator tether. They say it is feasible, with present-day or soon to be available technology, to build a 20-tonne space elevator climber with room for 10 tonnes of payload. The type of payload will require modifications to the climber design and affect the stresses in the climber and in the space elevator tether. Their paper provides a design summary of the 20 tonne climber, as well as the concept for a liquid oxygen payload using carbon reinforced polymer tanks. The stresses on the payload supporting arms and also on the climber wheels and tether are described and improvements to the climber design as well as different payloads are considered.

Suitable materials for constructing the tether are also mentioned by John Knapman in his discussion of innovation and research into space elevators. He notes that graphene super laminate is the most promising candidate – it has the right properties and while not long enough for a space elevator, it is able to add strength to carbon composite materials. Progress is also continuing into multi-stage space elevators, supported dynamically using magnetic levitation, which have the advantage of being built with less strong materials which are already available. Another aspect of Knapman's paper covers the commercial and scientific opportunities offered at the space elevator's nodes or ports. One of the possibilities he discusses is the ability for interplanetary travel from the apex anchor. Without the use of fuel or the need for spacecraft to carry reaction mass, the solar system and near-interstellar space can be explored at will without having to wait a long time for planetary alignments and gravity-assist manoeuvres. He observes that the gentle launch method from the apex anchor would remove the need to make delicate payloads robust enough to withstand the forces of a rocket launch.

This idea of interplanetary travel is the subject of the paper by Peter and Cathy Swan who, after considering how space elevators will open up the heavens for humanity because they are able to lift massive payloads off our planet with unmatched efficiencies, propose a mission for humans to have a round trip to Neptune with a space system capable of supporting a decade long mission. Two factors make this kind of mission more feasible. One is assembly of space systems (e.g. space elevators and their components such as climbers, or spacecraft) of any mass above the gravity well at the apex anchor. The second is the transformational characteristic of rapid release and higher velocities obtained at the apex anchor. The authors' argument is that there needs to be a permanent transportation infrastructure with rockets and space elevators being complementary and cooperative in order to enable a space-faring future.

Assembly of systems and components in space and the use of local materials has been looked at before. For instance, Jerome Pearson believed that lunar space elevators would be able to provide abundant raw materials and manufactured products that could be continuously delivered into Earth orbit for development of extensive space facilities for both business and pleasure [3]. And it is to a lunar space elevator that Arthur Woods, Andreas Vogler and Patrick Collins turn to in this issue for their Greater Earth Lunar Power Station (GE⊕-LPS) which would be constructed with lunar materials. Construction of the GE⊕-LPS would require the establishment of industrial-scale automated mining and manufacturing processes on the Moon, with a lunar space elevator deployed as a transportation system to move solar power satellite components from an anchor point on the surface of the Moon to a docking and assembly station at L1. While pointing out some advantages as well as technical challenges, the authors consider that a lunar space elevator would be an enabler of a cislunar economy and could perhaps be a precursor of an Earth space elevator.

4 AFTERWORD

The emergence of the modern-day space elevator has really only been solidified in the last few years and the assessment of new materials for the all-important tether has added an unstoppable impetus. Notwithstanding the issues with rockets, there needs to be a Dual Space Access Strategy that leverages the advantages of rockets with the advantages and benefits of space elevators. The idea, as these articles in this special issue show, is that the space elevator, dubbed the Green Road to Space because of its environmental considerations, can become a new and permanent transportation system which overcomes many of the problems associated with rockets whilst providing substantial benefits in the effort to solve the issues faced on Earth at the same time. Such a Space Elevator Transportation System (SETS) operating within a Galactic Harbour – inherently similar to a cargo ship harbour or container port but in space rather than on land – would enable continuous and integrated supply chain operations moving customer payloads from access cities or entry ports to exit or destination ports and beyond. The Galactic Harbour with its multiple space elevators would provide the logistic infrastructure for the movement of massive cargoes from the Earth to and between nodes and on to the Moon, Mars, Neptune and elsewhere in the solar system [4]. With a space elevator transportation system hopefully up and running towards the end of the next decade, then the aspirations set out in these five papers in this special issue are highly apposite.

REFERENCES

1. D. Raitt, "Space Elevators: a History", Lulu, Morrisville, 2017. ISEC History 2017-1. Available at: https://www.isec.org/studies/#history [last accessed 24 August 2023]
2. D. Raitt, "Space Elevator Architectures." *Quest*, **29**, 1, 2021, pp. 17-26
3. D. Raitt, "Jerome Pearson and Space Elevators", *JBIS*, **76**, 5, May 2023, pp 178-184
4. M. Fitzgerald, "Galactic Harbours", *Spaceflight*, **65**, June 2023, pp. 16-17