Modern day space elevators

The eighth space elevator architecture, as a permanent space transportation system, has remarkable transformative capabilities

By Cathy Swan

Modern-day space elevators have emerged over the last four years within the International Space Elevator Consortium (ISEC) community after growing through eight distinct system architectures and they have remarkable strengths. The basic premise, as shown in a 2020 ISEC study report *Space Elevators are the Transportation Story of the 21st Century* by this author, and others, is that elevators can lift about 30,000 t to geostationary orbit (GEO) in one year, more than humanity has lifted in its entire spaceflight history. Since 1957, only about 20,000 tonnes has been placed in low-Earth orbit (LEO). A key factor is that an elevator creates economic growth at both of its ends and along its vertical path. The concept is similar to the opening of a bridge across a valley, enabling economic growth at both ends and along the path. This bridge to space promises to open vast regions at GEO and beyond to governments, commercial ventures and entrepreneurs.

The case for space elevator architectures has grown stronger over the last five years as candidate materials for its tether have been tested successfully. The tether must be long enough and strong enough to carry large payloads into space on a daily basis, safely, routinely, inexpensively and in an environmentally friendly way. The timing of this testing could not be more beneficial as humanity is in the third decade of this century and the demands on civilisation become more apparent.

Space elevators can be developed into a permanent transportation infrastructure that can not only deliver large quantities to GEO and beyond but also enable the construction of huge systems at its apex. These systems can provide power for terrestrial infrastructure or house vast datacentres powered by the Sun. There is also the concept of the "galactic harbour" architectures which are another permanent transportation system architecture (see pages 16-17). This eighth architecture has two space elevators rising from an Earth port with GEO regions for assembly, repair, refuelling and two apex release points for flinging payloads to the Moon and beyond.

The eighth architecture has six distinct strengths that can provide a green road to space with

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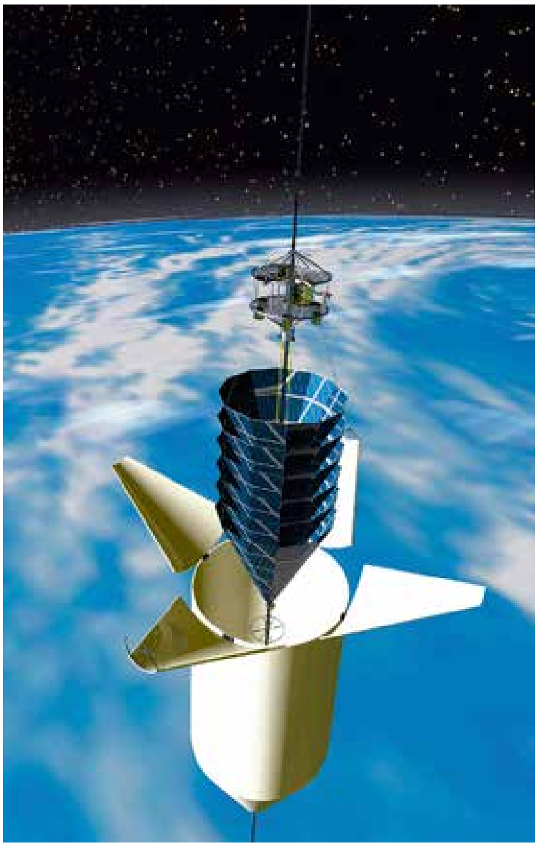

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advantages such as tether climbers able to deliver payloads to appropriate release altitudes. The first distinct strength is an elevator's ability to ascend payloads on a daily basis, routinely, safely and inexpensively. Those payloads could be probes going to Mars. A useful space probe mass of 14 t could be raised to the apex anchor and released, propelled by the Earth's rotation. Released at the right time, a payload can go to Mars almost any day of the year on different paths, eliminating the 26-month launch window for Mars, Earth alignments.

The second strength is a change in the economic paradigm to focus on the value to investors and not on the cost to the consumer. This economic paradigm change was set out in the 2021 conference paper *Changing the Economic Paradigm for Building a Space*

Elevator, by Kevin Barry and Eduardo Pineda Alfaro. They claim that this economic strategy helps transition thinking from early discussions of access by rockets versus space elevators towards what can be enabled by developing permanent space infrastructures. A key part of this paradigm shift is that the infrastructure's value comes from a reduction in transaction costs, with frequent ascents, and therefore higher productivity.

DAILY ASCENTS

The third strength follows directly from that frequent utilisation. The expected initial operational capability (IOC) of six space elevators is 30,000 t per year and its full annual operational capability (FOC) is 170,000 t. The fourth strength stems from those apex release points enabling high velocity transits to the Moon, Mars and beyond. An elevator's apex anchor, 100,000 km from the Earth's surface, is a high rotational platform resulting in a linear velocity release of 7.76 km per second. This speed is sufficient to reach the lunar surface in about 14 hours and Mars orbit in 61 days, with a range of trip durations dependent upon planetary orientation.

The fifth strength is the environmental case for elevators as they ensure environmentally neutral operations. This is according to the ISEC 2021 study *Space Elevators are the Green Road to Space* by Jerry Eddy, and his fellow authors. Solar energy for tether climbers' motors ensures there is no combustion within the atmosphere and no hardware left along the way. As such, their operations are green. In addition, this capability ensures success within the space solar power arena by delivering massive satellites to GEO orbit to reduce our fossil fuel dependence and to help stop global warming.

The sixth strength is improved satellite and spacecraft engineering. The shake, rattle, and roll of rocket propulsion is very stressful to payloads. The extraordinary set of requirements due to the launch environment inhibits the design of space payloads and restricts design flexibility. In addition, the restrictive rocket fairing enclosing the payload for launch has design implications. The extra volume available in a space elevator tether climber, and the soft ride, enable far more design flexibility for customer payloads going to GEO and beyond.

The final strength is the assembly of huge spacecraft in GEO and all its advantages. Without size restrictions of a fairing and daily ascents, the apex anchor release point could be a robotic factory for a starship. As well as the aforementioned velocity of 7.76 km per second, the vast robotic, or crewed, spacecraft could have its own propulsion. The elevator means spacecraft of almost any size can be built and flung towards any object inside the Solar System and even to escape the Sun's gravitational pull.

The restrictions on launch opportunities and mass towards Mars is hugely impacted by the restrictive 26-month Mars launch window. While conducting its 18-month study of interplanetary flights, ISEC concluded that spacecraft being released from an apex anchor was the answer. SpaceX is said to need one million tonnes sent to the surface of Mars. With an elevator FOC of 170,000 tonnes per year, that million can be achieved in less than six years. Such

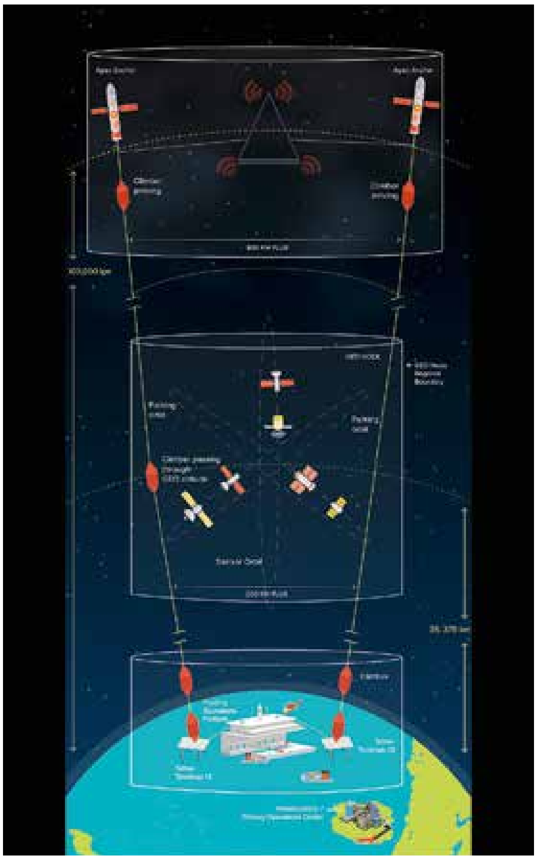
PHOTOS FROM TOP: FRANK CHASE/CHASEDESIGNSTUDIOS.COM / INTERNATIONAL SPACE ELEVATOR CONSORTIUM

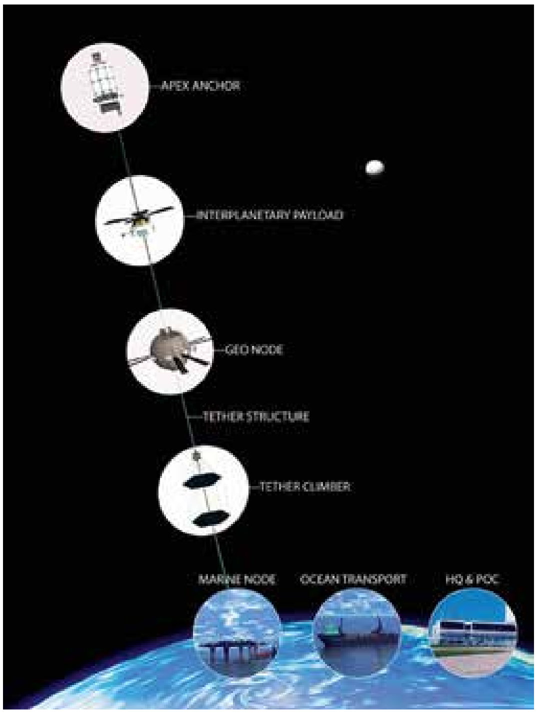
CLOCKWISE FROM LEFT

A tether climber emerges from its protective box at about 40 km altitude after transiting through the atmosphere.

This infographic shows the galactic harbour architecture.

This graphic shows the separate segments of the space elevator transportation system from the payload delivery ships, the Earth ports and the various parts of the elevator.





strengths of modern-day space elevators surfaced as the community recognised that commercialisation of space activities will drive the capability to deliver logistics to diverse locations for otherwise challenging opportunities. Earth need not have just one elevator, there is the concept of three competing galactic harbours. Spread around the equator, they can ensure that multiple government and commercial customers can support ventures at GEO and beyond which require the kind of massive logistics support that only modern day space elevators can deliver. SF