Cooperation & competition

A dual space access strategy leverages the best of both space elevators and rockets for a greener road to space

By Peter Swan

Off-planet migration and the drive to save our own world demand more capability to lift and deposit payloads at locations that require a huge expenditure of high energy to reach.

Geostationary orbit (GEO) is one such location and it will be especially helpful for potentially solving many of humanity's problems such as helping climate change with greener energy sources. Going beyond GEO is becoming more and more realistic as explorers are vying to go to the Moon in this decade while others are planning to go to Mars in the very near future. As the International Space Elevator Consortium (ISEC) was studying these two potentially demanding destinations, it became necessary to describe an environment where advanced rockets and space elevators work cooperatively to deliver logistical support for humanity's near-term dreams. ISEC's recently completed study *Space Elevators are the Green Road to Space* and on-going dual space access architecture study have led to some very intriguing results.

The first conclusion is that our visions match the dreams of so many to lift tremendous amounts of mass to high locations and actively operate beyond GEO. The second is the realisation that ISEC must create an overall architecture for the space community called "dual space access strategy". The third is that space elevators offer a green road to space that ensures massive logistics without destroying the environment we are trying to save. The fourth is that the space elevator developmental programme is ready to be initiated as tether material candidates now exist (See pages 24-27).

About 18 months ago, ISEC finished a study on what it termed "the green road to space" and changed its vision to recognise the remarkable conclusions and concepts inherent in this mission.

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The ISEC vision is that space elevators are the green road to space to enable humanity's most important missions by moving massive tonnage to GEO and beyond. This will be accomplished safely, routinely, inexpensively, daily and they are environmentally neutral. A major focus of this study was the analysis of the environmental impact of raising cargo from the Earth's surface to GEO and beyond.

The report summarises the magnitude of damage caused by burning rocket propellant inside our atmosphere and the danger of depositing major portions of a space mission in Earth's orbit after their use. Large rocket bodies in low-Earth orbit (LEO), and elsewhere, will contribute to future debris fields and impact on existing LEO missions. Several studies have been conducted looking at the damaging effects of rocket fuel residuals inside Earth's atmosphere. Their conclusions were that there are no other methods to satisfy government and commercial missions except rockets. The impact from the burning of propellants in the atmosphere was also deemed acceptable at a low level of launches, around 130 a year.

However, there are several studies that raise the question, what happens when we have thousands of launches a year? Elon Musk has stated that SpaceX plans on 1,000 launches a year to deliver one million tonnes to support Mars settlements. A solar power satellite mission requires 5,000,000 t taken to GEO to supply 20% of the world's power needs in 2050. For a sunshade in space, 20,000,000 t is required and ESA's proposed Moon Village habitat would need about 500,000 t delivered to the lunar surface.

DUAL ACCESS

With a space elevator system whose tether climbers use solar energy for propulsion the environmental impact of lifting vast quantities is non-existent. And

PHOTO: THE SPACE ELEVATOR COMPANY

ABOVE
A tether climber is seen at the top of the picture and the tether it is climbing is extending into the distance down to Earth.

space elevators have the capability to lift more cargo in one year than humanity has achieved up to the present moment (See pages 18-19). The ISEC 2021 "green road" study also looked at several missions which would include space solar power, the removal of high-level nuclear waste for permanent disposal, and Sun-Earth Lagrangian point-1 (L-1) solar shades. Each of these missions would significantly enhance the health of the Earth as they deposit massive cargo in GEO, L-1 and low solar orbit.

The ongoing ISEC study, *Dual Space Access Architecture*, is taking the results from the aforementioned 2021 study and developing concepts for a complementary and competitive approach. This has a strategy supporting space missions with two parallel lift capabilities. When looking back and thinking of Apollo, and now looking forward to Artemis, people tend to forget how extremely difficult the rocket equation is to satisfy. When looking at delivery statistics for the rocket equation, it becomes apparent that reusability and frequent launching will drive down the cost, but it will not impact the percentage delivered to the destination – in fact it is reduced to ensure reusability.

Historically, humanity has only delivered some 20,000 t to orbit because of the rocket equation. This results in the ridiculous numbers of 4% of launch pad mass delivered to LEO and 2% to GEO including for those lunar or Mars transition trajectories. But only 0.5% of the launch pad mass is ultimately delivered to the surface of the Moon and beyond. The good news about rocket propulsion is that industry is now achieving more and costing less through a more commercial approach.

The incorporation of reusability characteristics for rocket launches has improved the situation significantly. Rockets have tremendous strengths, and they have initiated many new missions to go beyond LEO. One mission essential strength of rockets is their ability to move people through radiation belts rapidly. SpaceX's Falcon 9 (F9) launches the reusable SpaceX Dragon crew and cargo spacecraft, and the F9 launcher has a reusable first stage. The launch of SpaceX's fully reusable Starship took place in April and Jeff Bezos' Blue Origin New Glenn is another reusable rocket in development. As much as rocketry has improved, those ludicrous percentages for launch mass to LEO, GEO and beyond show it is a transportation technology inadequate for humanity's goals. To truly realise the benefit of space for humanity, huge GEO satellites with masses of 2,000-3,000 t each for space solar power are required. The world will need up to 500 such solar power satellites to meet its energy needs. To settle the Moon, ISEC envisages 500,000 t being delivered to the Moon's surface. And for the great goal of Mars, Elon Musk's oft quoted figure of one million tonnes is not unrealistic.

The solution to the rocket conundrum is a dual space access strategy with all the benefits of space elevators, but there are limitations. The first of which is that space elevators are unlikely to be available for operations until around 2037. However, »

« ISEC's developmental programme will be starting soon with plenty of time to reach that date while developing major portions of the architecture. Access to LEO is likely to always be reserved for rocket access. A third limitation is that initial operations will be robotic and will grow towards human capabilities long after initial operations.

The good news is that these three shortfalls are far outweighed by the remarkable characteristics that a space elevator and its developmental programme brings. Access to space should be routine with a permanent infrastructure, essentially a bridge to space, which can become a logistics route for all missions at GEO and beyond. This permanent transportation infrastructure defines the space elevator portion of the cooperative and competitive dual space access strategy. The characteristics of this are fourfold.

The first characteristic, avoiding the rocket equation, leads to 100% delivery of mass at lift-off to mission destinations, 70% of which is cargo and 30% the tether climber, which is fully reusable. Neither are pollutants left behind by the rocket's engine exhaust gases and no falling or space debris created. The second characteristic – supporting massive logistics needs – is that space elevators' initial operational logistics capabilities are 30,000 t per year to GEO and beyond. That is expected to grow to 170,000 t per year once the elevator architecture reaches its full operational capability.

The third characteristic – green road to space – was described above, but essentially, it ensures neutral operations inside the galactic harbour environment [see pages 16-17) and empowers missions that can assist the greening of our planet. The fourth and final characteristic, enhancing future space missions, is that the space elevators can meet the key orbital needs of missions with a release location along the tether's entire length. The GEO altitudes match the middle of the tether which means a problem free release and ease of rendezvous for a waiting space tug that will move the payload to its final location.

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It is the release point at the apex anchor that delivers the most advantages with its inherent imparting of a velocity of 7.76 km per second for any payload. This enables a payload to go beyond Mars without a need for its own propulsion system, unless slowing down to enter some other orbit is required. For Mars itself, 7.76 km per second can get a payload to the red planet in 61 days (See pages 18-19).

Assessments of the shortfalls and strengths of advanced rockets and space elevators show that the future is bright and the dreams of many can be achieved. One element of this statement is the realisation that future demands to lift mass to GEO and beyond will be huge if those dreams are to be achieved. As such, the space community should encourage and support a dual space access strategy. The multiple destinations, complexity of future orbits, large demands for delivery of mass to distant destinations, and demands for multiple launches per day mean both methods can, and should, cooperate and compete. While neither can do it by themselves, competition will ensure commercial values are incorporated and that each will innovate and improve, leading to a remarkable future for space access for all. SF

PHOTOS CLOCKWISE FROM LEFT: OBAYASHI CORPORATION / ADYM PASKO / NASA/PAT RAWLINGS / SPACEX

CLOCKWISE FROM TOP LEFT

This image shows a concept Earth port as set out in the Obayashi Corporation's space elevator study.

This artist impression shows a view of the geostationary orbit "GEO Station" structured across three elevator tethers and a solar powered tether climber can be seen below it.

This image, created by artist Pat Rawlings, shows a space elevator concept that was the subject of studies by NASA's Marshall Space Flight Center's Advanced Projects Office more than 20 years ago.

This shows the thirteenth landing for this SpaceX Falcon 9 first stage booster that took place on 9 March 2023 after it had launched OneWeb satellites.