Solar sails - The key to deep space odysseys

Solar sails are an underutilized method of spacecraft propulsion, making use of the easily available solar energy in inner-solar space to accelerate via radiation pressure. While the technique is only practical for small probes, the method is gaining popularity in the scientific community as a means of cost-effective thrust, particularly for sustaining interstellar travel.

Laurence Russell, News & Social Editor, NewSpace International

After conquering the logistical barrier of breaking with Earth's gravity, spacefaring faces a second, far greater logistical challenge: Provisioning for journeys between celestial bodies.

The amount of rocket fuel required to enter orbit alone is staggering, but around the same amount again is needed for a trip to Mars, all of which is practically doubled in the case of return journeys. The sheer tonnage of chemical propellant needed for the more ambitious space voyages has long been one of the primary barriers to advanced space exploration.

An eloquent answer to the problem may be emerging from solar sail research, which appears to have undergone several eureka moments in recent years. The promising results seen from trials of NASA's Near-Earth Asteroid (NEA) Scout, a sophisticated CubeSat probe set to be placed in cis-lunar space in order to observe nearby asteroids and support mitigation strategies for planetary defence, have seen space scientists start taking solar sails more seriously.

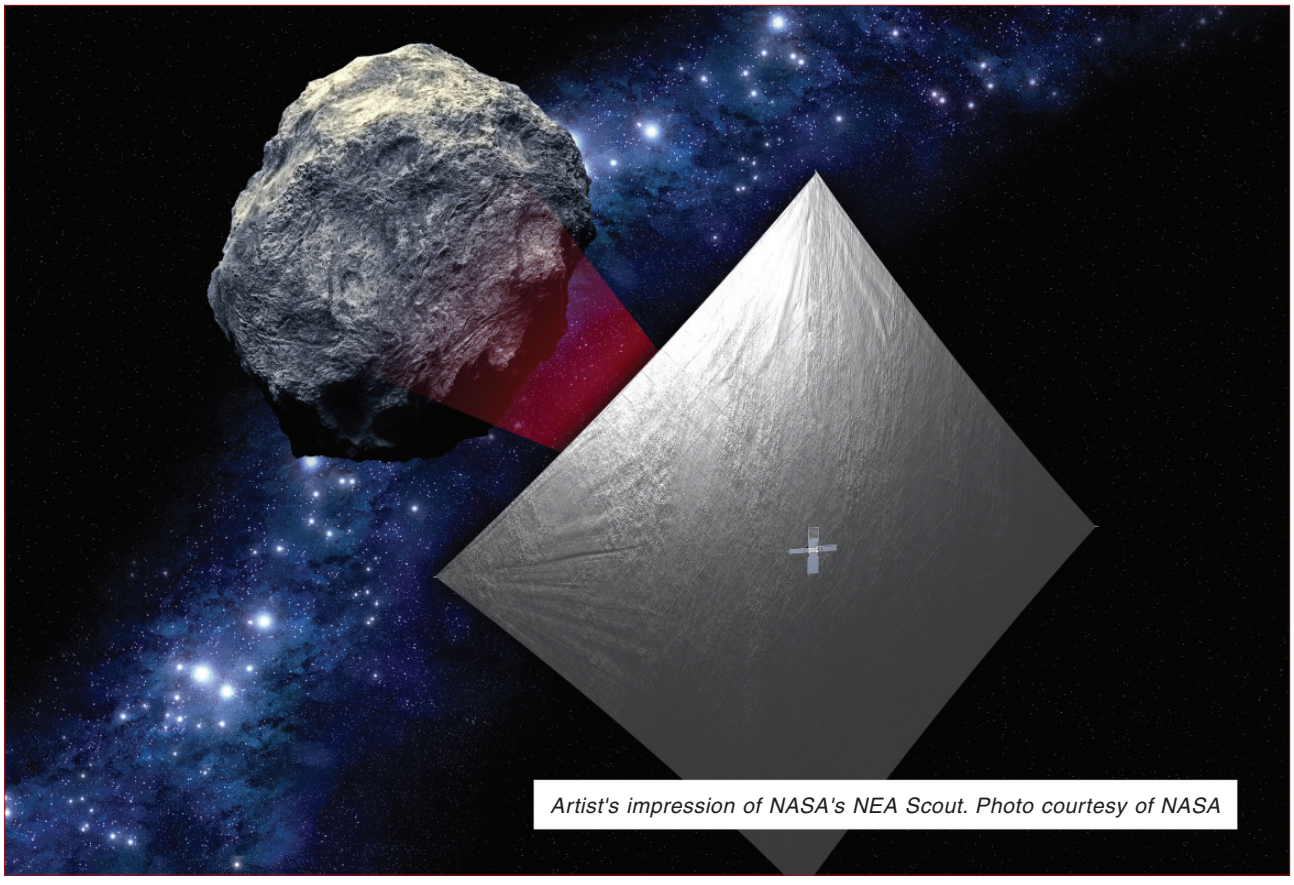
Renewable resources may be handy on Earth, but in space they're invaluable, and in the inner-solar space of our star system, no resource is more renewable than solar power.

Going interstellar – Sailing the stars into the wild unknown

On a recent live web panel courtesy of Roccor - "Where will Solar Sailing take Small Satellites?" - in which a league of experts discussed the future of the field, hosted by Scott Tibbitts, CEO of Starsys Research and Katasi, Inc., the prospect of interplanetary probes making use of solar sail acceleration was hotly enthused over.

"The trick is the constant acceleration," explained Dr David Spencer, Mission System Manager, Mars Sample Return Campaign at NASA JPL. "Even a very small acceleration applied over a massive timeframe can build to an extreme velocity in space, and so it's one of the few technologies that can approach an interstellar trajectory and arrive within the span of a human lifetime."

Once out of inner-solar space, Dr Spencer explained



Artist's impression of NASA's NEA Scout. Photo courtesy of NASA

that a probe could detach its sails for even lighter mass, and upon reaching neighbouring systems, begin imaging its exoplanets, charting their continents to recover invaluable insights into alien worlds.

"The most realistic step we can take now is technology demonstration missions in interstellar space," said Dr Artur Davoyan, Assistant Professor of Mechanical and Aerospace Engineering at the University of California, Los Angeles (UCLA). "There are so many unknowns out there and so much evolving, emergent science that we need to see put into practice."

The proverbial revelatory moment in which the technology of solar sails went from impractical curiosity to crucial method of space exploration was described by Les Johnson, Solar Sail Principal Investigator at NASA. "It hit me during the smallsat revolution. As spacecraft mass was effectively reduced, suddenly the area/mass ratios required for effective solar propulsion lined up. When you do the numbers, you can see that within real physics, not warp cores or dark matter drives, but the actual behaviour of light, it's possible to take a robotic probe to another star system of exoplanets."

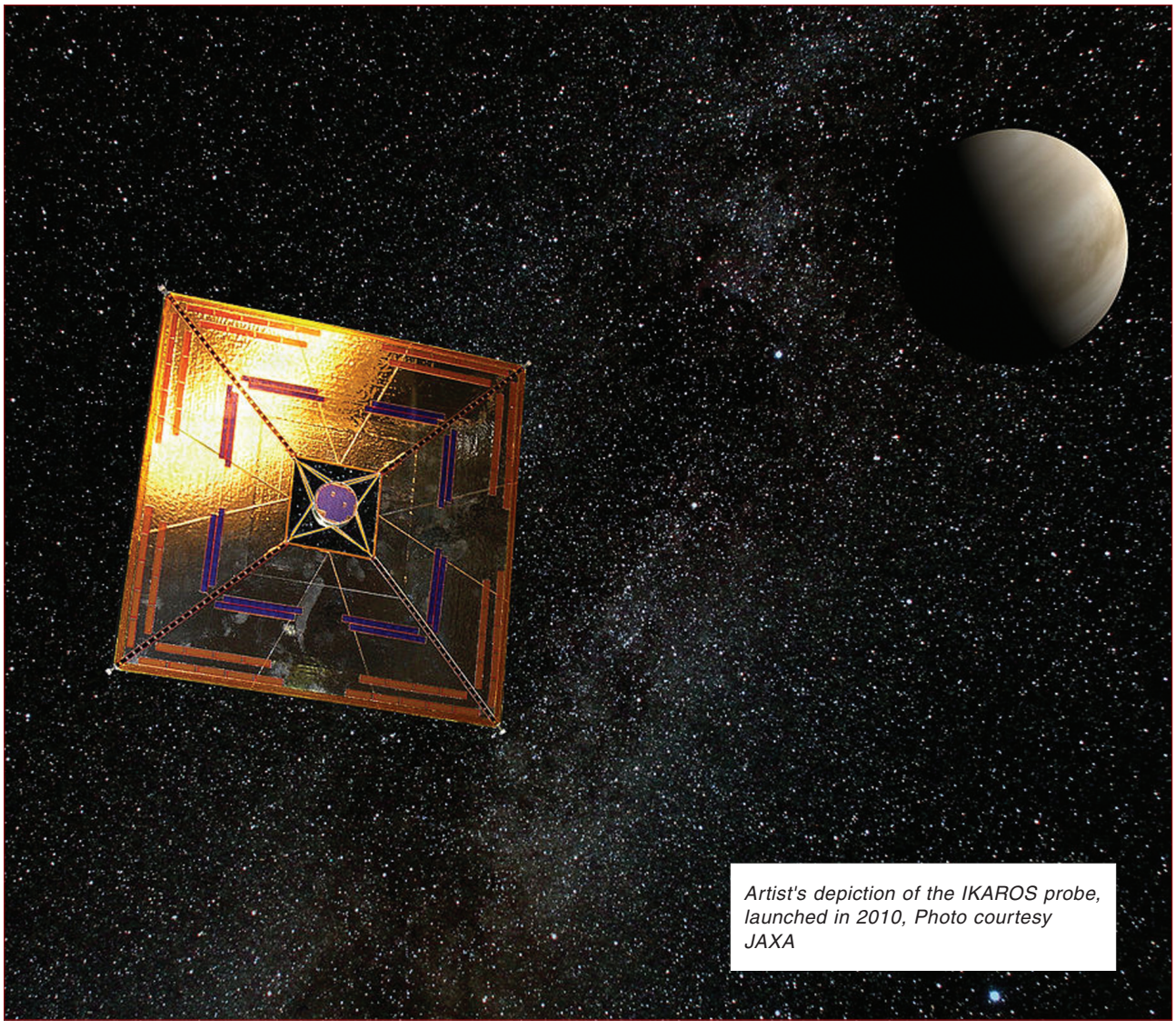
The US$100 million Starshot initiative hypothesised in 2016 plans to launch a swarm of tiny spacecraft with gossamer-thin sails dubbed 'starchips' to Alpha Centauri. Hypothetically, the starchips would accelerate to 20 percent the speed of light to reach the neighbouring system within 20 years. A highly advanced laser array is required to propel the starchips at such fantastic speeds. The kind that modern science isn't yet capable of constructing. Such an array is estimated to cost between US$5 and US$10 billion, assuming the grey areas can be accounted for during R&D.

Inner-solar vigilance – A new standard for probes technology?

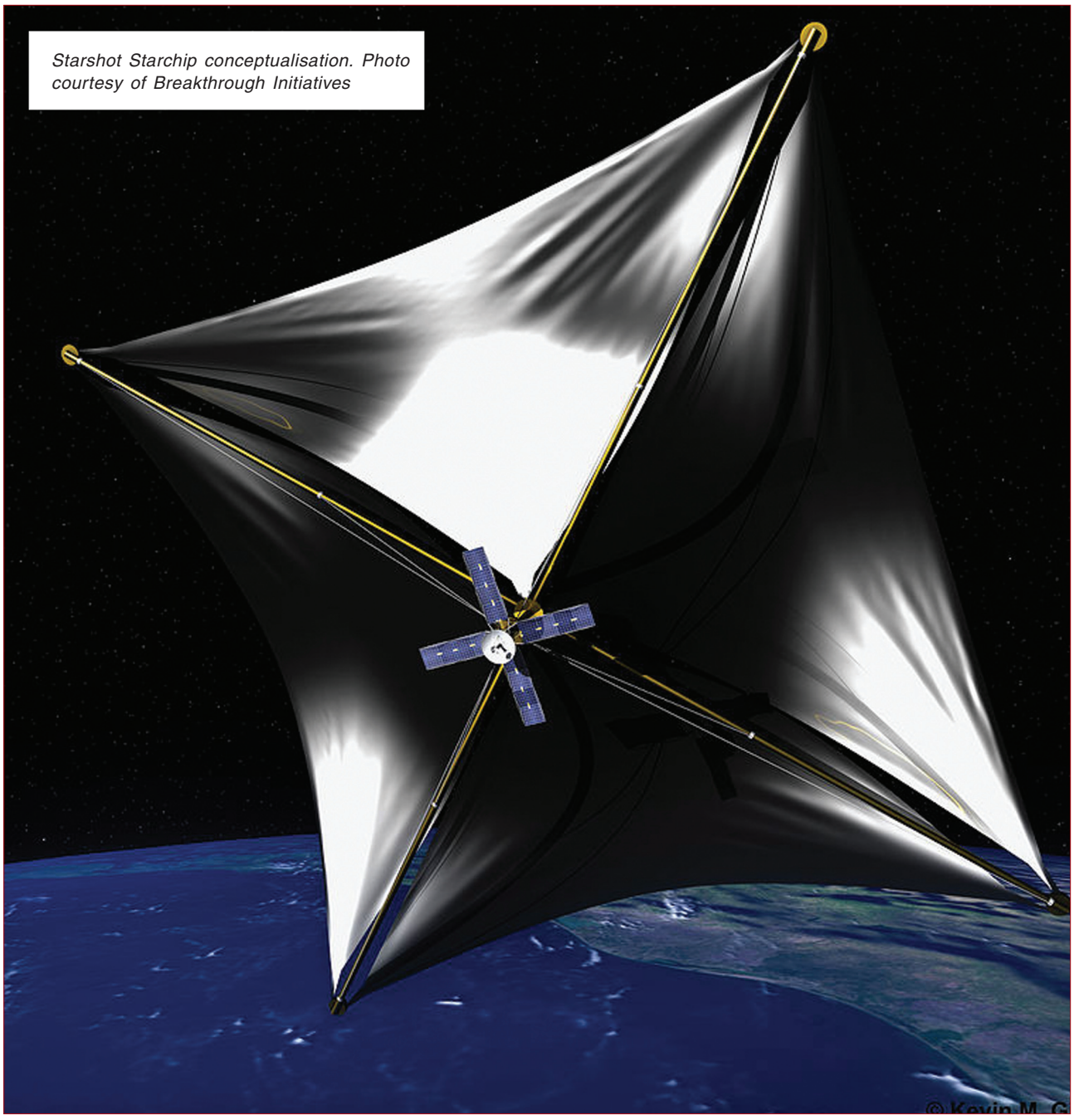
While exoplanetary survey isn't yet practical, outer solar exploration is showing more promise. With extreme conservation of mass through probes constructed from aerographite carbon foam, 15,000 times lighter than aluminium, a solar sailed probe would not need a laser array to reach high velocity. The resulting microprobe could potentially weigh just 2.3mg. After prototyping, it's predicted that these aerographite probes could cost US$1,000 or less.

With an onboard 1g, 32W laser payload, such a probe could accelerate to 114,000mph. Enough to reach Pluto from Earth in 3.9 years without an ounce of chemical propellant. The laser could then help astronomers on Earth detect gravitational effects which could reveal the presence of bodies too dark and cold to see from Earth, such as the theoretical Planet Nine.

More aspirationallly, launching the same vessel close to the sun (0.04 AU away), an aerographite craft could



Artist's depiction of the IKAROS probe, launched in 2010, Photo courtesy JAXA



Starshot Starchip conceptualisation. Photo courtesy of Breakthrough Initiatives

reach 15.4 million mph, which could reach Proxima Centauri in 185 years. However, aerographite drones are also speculative, as there has never been an aerographite structure larger than a few centimetres, and an interstellar probe would require a design a few metres large.

"It's really important to get creative and think big here," edDana Turse, Director of Emerging Products at Roccor. "Extremely large apertures are possible with this technology. What if we manufactured sails of 10,000 square metres, enabling a far larger payload? This technology can be scaled up to enable vastly more applications that haven't been broadly considered yet."

While the most excitement for solar sails appears to be deservedly centred on the possibilities for interstellar travel, more contemporary applications lie closer to NEA Scout's purpose in effectively monitoring our solar system. The Earth has managed to sidestep a number of cosmic catastrophes in our history through sheer luck, but we are fast approaching the era in which the dangers of incoming asteroids and freak solar storms are becoming mankind's responsibility to predict, prepare for, and wishfully prevent.

Later in the panel, Dr David Spencer argued that: "Solar sail spacecraft are uniquely well-suited for providing solar storm monitoring because of their capability in non-Keplerian orbit, which is perfect for gathering solar data."

While space exploration and planetary defence are noble and pointedly essential applications of space technology, they may not be driven by the market at the same speed as NewSpace interests. The revenue streams involved in discovering new worlds, and safeguarding old ones may seem obvious, although without the snappy return period that traditionally compels governments and investors to award funding, the full potential of solar sailing may not be realised as quickly as other, more lucrative space technologies. ■

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