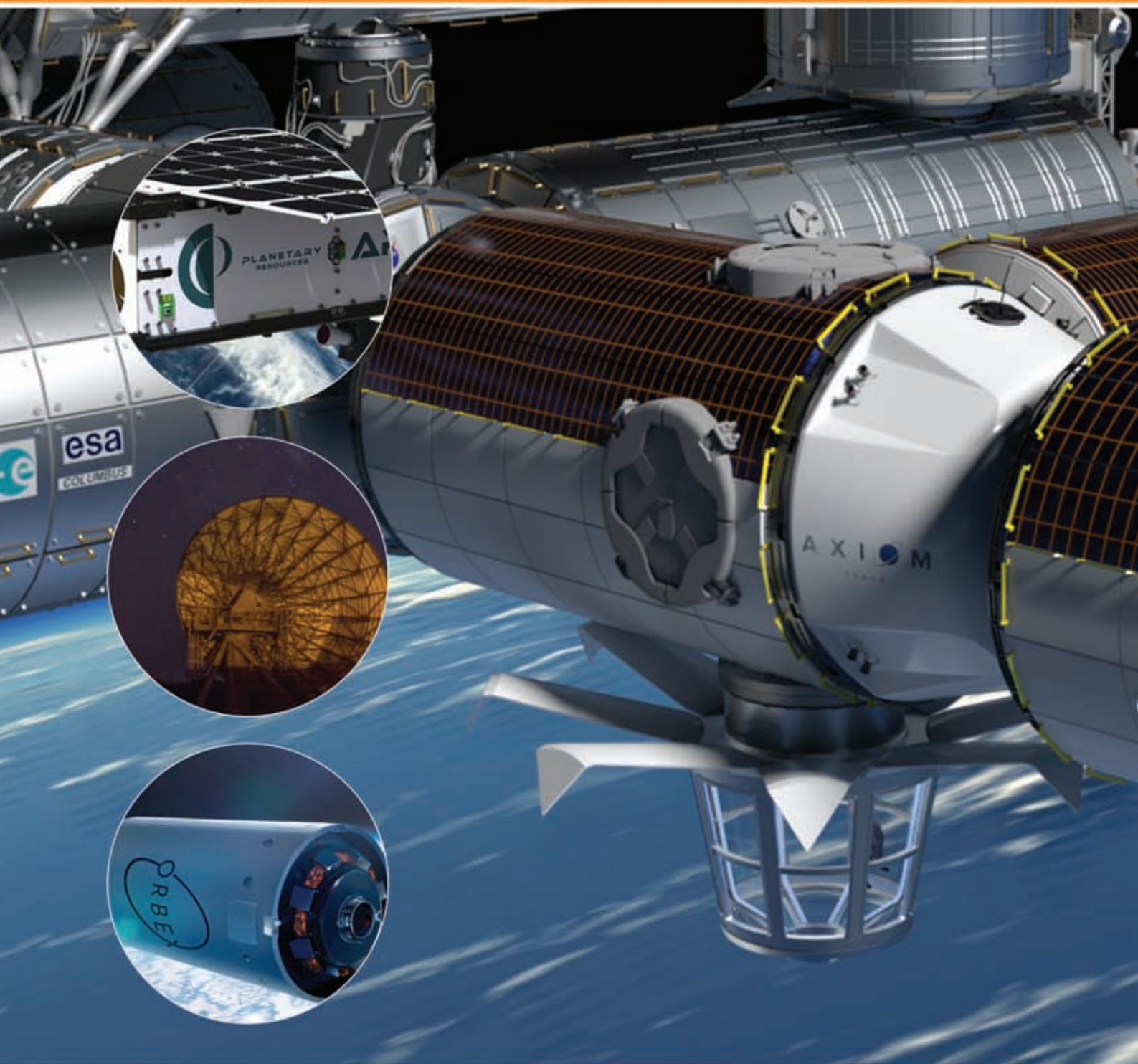


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**Dr Amy Saunders****Editor**

“ Towards the end of 2018, it was reported that a new Dwarf Planet dubbed Goblin – for its Halloween 2015 discovery – had been confirmed. The planet, officially called 2015 TG387, reportedly provides new evidence for the now infamous but yet-to-be-proven Planet 9 or Planet X.

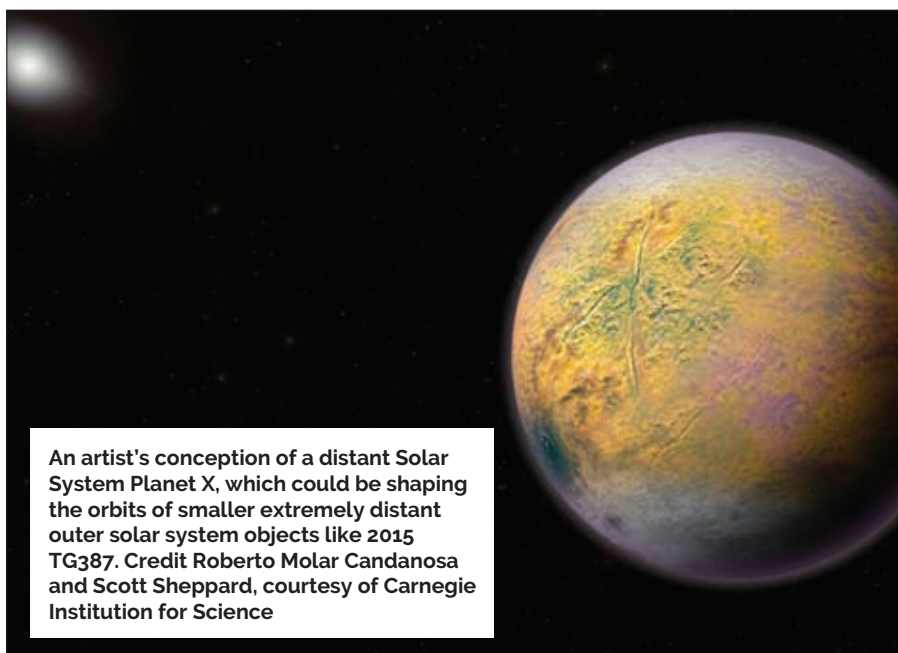
Carnegie University's Astronomer Scott Sheppard and team located Goblin with the Subaru Telescope on Mauna Kea, Hawaii. The Goblin's highly-elongated orbit, which takes it as far as 2,300AUs from the Sun, means that it doesn't interact with other planets in our Solar System, but is bound to the Sun as part of a cluster of Extreme Trans-Neptunal Objects (ETNOs). The Inner Oort Cloud Objects (IOCOs) sub-group, which also includes 2012 VP113 (another catchy name) and Sedna, are hard to detect, since they spend the vast majority of their time far away from the Sun.

It's these IOCOs that have caused astronomers across the globe to search for the elusive Planet 9. Their reasoning? The similarity of their orbits is indicative of the influence of an as-of-yet undiscovered Planet 9, which is thought to be located hundreds of AUs away from the Sun. Indeed, some argue that the chances of these three planets having such similar orbits is only a fraction of one percent.

Alternative theories to the Planet 9 idea include the hypothesis that, during the early formation of the Sun, the extreme gravity of a close stellar encounter could have pulled these IOCOs away from the Sun and left them in a 'fossilized orbit.' Others have suggested that enough minor planets might exist which are capable of influencing each other's orbits over many million years through 'self-gravitation,' gradually travelling further away from the Sun.

The challenge in finding Planet 9 lies in its distance from us. We know that its mass is estimated at 2-4 times that of the Earth, but nothing about the amount of light it would reflect, rendering it extremely difficult to identify and locate. Nevertheless, the confirmed discovery of Goblin is yet another feather in the cap of the Planet 9 hunters. While today, the search suffers from a serious lack of data, that may change in the years to come as deep space exploration projects advance. ■

Searching for the unknown



An artist's conception of a distant Solar System Planet X, which could be shaping the orbits of smaller extremely distant outer solar system objects like 2015 TG387. Credit Roberto Molar Candanosa and Scott Sheppard, courtesy of Carnegie Institution for Science



Front cover: Axiom Modules connected to ISS. Photo Axiom

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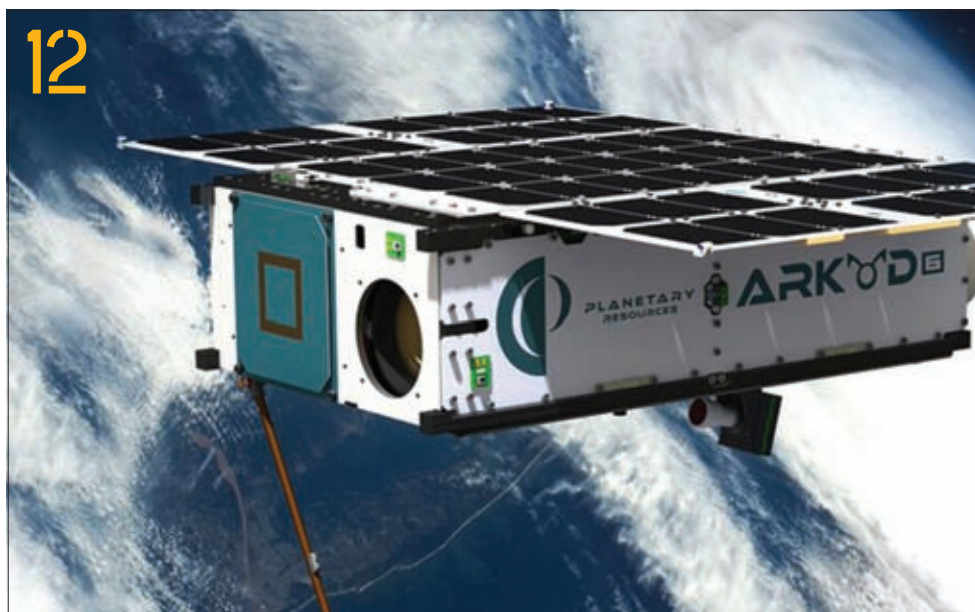
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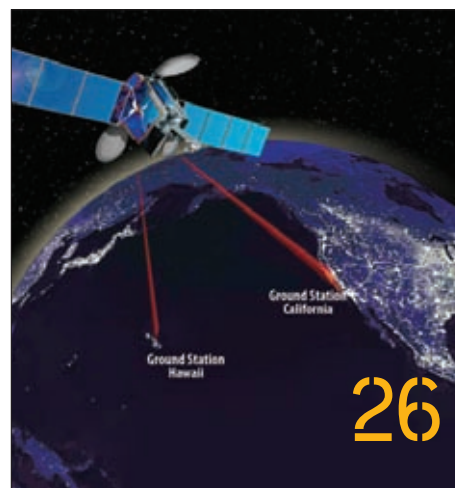
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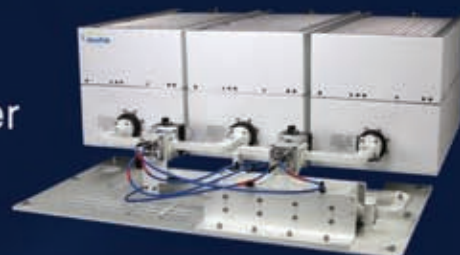
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Isotropic Systems raises \$14 million in Series A Funding led by Boeing HorizonX Ventures to advance space-based connectivity

Isotropic Systems Ltd., the next-generation integrated satellite terminal solution provider, has announced a \$14 million Series A round of funding led by Boeing HorizonX Ventures, with participation from WML, Space Angels and Space Capital.

"The Series A financing builds on an exceptional year for Isotropic which saw a rapidly growing roster of strategic partners and customers who are poised to unlock the full potential of high-throughput satellites and mega-constellations across all orbits," said John Finney, Founder and Chief Executive Officer of

Isotropic Systems. "Boeing's investment provides our team access to Boeing experts, testing labs, and other valuable resources to fast-track the deployment of our terminal solutions and to leverage our intellectual property across other space-based and wireless connectivity applications."

Leveraging a transformational optical beamforming technology to control the direction of radio waves, Isotropic Systems has developed communication terminal solutions that are significantly more cost-effective. Also they use significantly less power and yet achieve superior performance benefits for the end users.

The substantial reduction in cost and power combined with improved

performance result in newly-addressable markets and enable mass adoption of satellite communications.

"Isotropic's solution allows for increased capabilities at reduced costs for satellite service providers," said Brian Schettler, Managing Director of Boeing HorizonX Ventures. "This investment accelerates the expansion of space-based connectivity services to the mass market and continues Boeing's leadership in space innovation."

This new funding will allow Isotropic to accelerate the commercialization of its technology to benefit its satellite operator customers and to leverage its technology to explore new applications in adjacent markets. ■

PTScientists to examine future ESA mission on in-situ resource utilisation on the Moon

The European Space Agency ESA and ArianeGroup, as prime contractor of a consortium of ArianeGroup, Space Application Services and PTScientists, have signed a contract to study and prepare ESA's planned ISRU mission.

In space, in-situ resource use (ISRU) is the practice of collecting, processing, storing and using materials found or produced on other celestial bodies (Moon, Mars, asteroids, etc.) to replace materials that would otherwise be brought from Earth.

The ESA mission focuses on the use of the lunar regolith. Being able to extract water and oxygen from regolith is a prerequisite for a sustainable presence of humans on the Moon. In addition, the necessary fuel for future missions into deeper parts of the solar system could be produced in this way.

ArianeGroup and its subsidiary Arianespace, which will provide the Ariane 6 launch vehicle, the Berlin-based new-space startup PTScientists, which will provide the lunar lander, and the Belgian company Space Applications Services, which will provide ground segment, communications and related services, have joined forces to conduct this study.

The innovative and wholly European consortium will be able to provide services for the entire mission, from launch to transport of the payloads required for the ESA mission to the Moon, landing on the Moon's surface and communication back to Earth.

"We are very pleased with the confidence placed in us by the European Space Agency ESA. The award of the ISRU study to the strong consortium of ArianeGroup, SAS and PTScientists underlines the current shift in the space industry" says Robert Böhme, CEO and founder of PTScientists GmbH.

"The use of space resources could be a key to sustainable lunar exploration and this study is part of ESA's comprehensive plan to make Europe a partner in global exploration in the next decade - a plan we will put to our Ministers for decision later this year at the Space19+ Conference," added Dr. David Parker, Director, Human and Robotic Exploration at ESA. ■



QuadSAT secures £700,000 seed funding

QuadSAT, the drone-enabled antenna testing company, has closed its £700,000 seed round, led by Vaekstfonden, the Danish Growth Fund, with participation from Seraphim Capital and existing investors. The investment will enable QuadSAT to bring its innovative drone platform to the satellite communications industry, initially focusing on maritime and aeronautical applications.

QuadSAT's platform uses drone technology to test and calibrate satellite and VSAT antennas autonomously, mimicking an orbiting satellite that can simulate a ship or aircraft's motion. This method enables highly accurate testing while drastically reducing downtime.

Having started as a University project, QuadSAT is an innovative startup company. Based at Odense Robotics Start Up Hub, a Danish accelerator programme for robotics and drone startups, which provides premises and expert assistance, this investment follows an initial round of investment to establish the company in 2017.

Joakim Espeland, CEO, QuadSAT, commented: "Our technology alleviates a massive pain point for our customers and will ensure high quality communications with minimum interference at a competitive price. We're thrilled to be backed by our investors, including the team at Seraphim, which brings with it a great deal of sector-expertise as the world's leading space-tech focused venture capital fund."

QuadSAT was one of six companies to take part in Mission 1 of Seraphim Space Camp. Seraphim Space Camp is the UK's first accelerator for space-tech start-ups backed by Seraphim Capital, the world's first venture capital fund dedicated to SpaceTech. The programme aims to get Seed and Pre-Series A, space-tech companies 'investment ready' and to facilitate unique corporate relationships with some of the leading space corporates and agencies.

Of the programme, Joakim said: "Taking part in Seraphim Space Camp was fundamental to us really. Speaking to relevant industry players who were able to validate what we were doing had a big impact on us

and our future roadmap."

Rob Desborough, Seraphim Capital Portfolio Director and Director of Seraphim Space Camp commented: "We are very excited to be partnering with Joakim and the rest of the QuadSAT team. They were incredibly well received by our

corporate partners whilst on the Space Camp Accelerator and are first movers in a billion-dollar global market. With stringent industry standards in place, QuadSAT is solving a real challenge for its customers and will provide enormous benefit to the industry." ■



Drone-enabled antenna testing

Image: QuadSAT

Rocket Lab appoints Lars Hoffman as Senior Vice President – Global Launch Services

Small satellite launch provider Rocket Lab has appointed Lars Hoffman to the role of Senior Vice President (SVP) – Global Launch Services, as the company enters its second year of commercial orbital launch operations. In his role as SVP – Global Launch Services, Mr. Hoffman will lead Rocket Lab's sales, business development and customer experience teams to continue delivering frequent, reliable and tailored launch services to the small satellite market.

Mr. Hoffman brings with him more than 30 years of experience in national security and aerospace, following a distinguished US Air Force career and corporate executive roles in the commercial space sector. Mr. Hoffman joins Rocket Lab from his most recent role at SpaceX, where he was responsible for National Security Space (NSS) strategy and business development as Senior Director of Government Sales.

The appointment comes as Rocket Lab begins its busiest launch year yet, with monthly orbital missions scheduled across the company's two private launch pads in Mahia, New Zealand and Virginia, USA.

"Lars is a proven leader who will guide the Rocket Lab Launch Services team as they continue to deliver the premium launch service that the small satellite industry enjoys on Electron," says Rocket Lab founder and CEO, Peter Beck. ■

mu Space unveils plan to bid for space exploration projects

mu Space has revealed its ambitious targets for 2019, including the plan to enter into the projects of the US space agency NASA and other space exploration competitions.

In an interview at the international conference Pacific Telecommunications Council (PTC), mu Space CEO and founder James Yenbamroong laid out his vision and strategy to get his company to join in the space race.

"2019 promises to be challenging for mu Space. We're planning to engage with NASA to demonstrate our capacity to undertake big projects and to validate the technologies that we're currently developing -- from concept to testing to flight," James said.

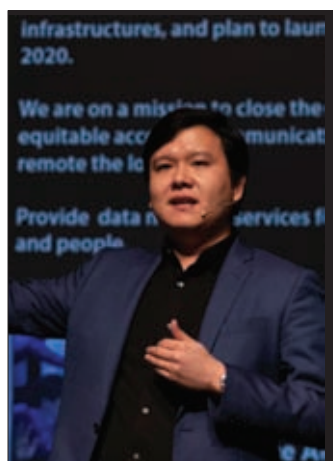
According to NASA, a USD 10.5 billion budget or over half of the space agency's USD 19.9 billion funding request for 2019 will be allocated to the space exploration programs. Some of NASA's biggest projects recently announced include the Commercial Lunar Payload Services, the development of a human landing system and the land development of the space agency's Kennedy Space Center.

"Aside from NASA projects, we're also targeting to join in the lunar exploration contest The Moon Race," James added.

The Moon Race is global competition aiming to develop technologies that could contribute to the sustainable exploration on the moon. It is backed by Airbus, Blue Origin and the European Space Agency. The competition's application period and details on monetary prizes are due to be announced to the public in the early part of this year.

"We're 100 percent prepared," James said when asked about the readiness of mu Space to take part in the projects. "We can acquire the knowledge and skills needed to differentiate ourselves from the competition, and to build a disruptive approach to space exploration. We also have a business entity recently set up in the US to bid for the projects," he explained.

mu Space, founded in 2017, develops space and satellite communication technologies to accelerate the adoption of Internet of Things devices and smart cities. In 2018, the company made history for sending into space the first payload from Asia to be onboard a Blue Origin rocket. mu Space plans to launch its own satellite in 2021, and to lead space technology development and encourage new space investments in Asia-Pacific. ■



Blue Origin breaks ground

Blue Origin celebrated the official groundbreaking for its world-class rocket engine production facility in January.

The plant will be built on 46 acres at the corner of Explorer Boulevard and Pegasus Drive in Cummings Research Park. The project includes more than 300 new jobs.

"It's a great day here in Rocket City," said Bob Smith, CEO of Blue Origin. "Thanks to the votes of confidence from United Launch Alliance, from the Air Force for national security missions, and from Huntsville and the state of Alabama, we are breaking ground on a world-class facility to produce our engines and power the next generation of spaceflight."

Blue Origin was selected by United Launch Alliance (ULA) in September of last year to supply its next-generation Blue Engine 4, or BE-4, for the first stage of ULA's Vulcan Centaur Rocket.

Blue Origin's BE-4 engine is the most powerful liquefied natural gas (LNG) fuelled rocket engine ever developed. Using an oxygen-rich staged combustion cycle, BE-4 is capable of producing 2,447 kN (550,000 lbf) thrust with deep throttle capability. BE-4 is currently undergoing full-scale engine development testing in company facilities in Van Horn, Texas. Full rate production will take place in Blue Origin's new engine manufacturing facility in Huntsville, Alabama.

The BE-4 is America's next rocket engine and is made for both commercial and government missions. The Huntsville manufacturing plant is expected to open in 2020, and the first flight test of the new engine is expected in 2021.

Blue Origin is a welcome addition to Alabama's roster of world-class aerospace firms, and its new rocket engine facility in Huntsville will expand the state's already robust capabilities in space flight," Governor Kay Ivey said. "Blue Origin is making a significant investment in Huntsville, and I'm certain the company will discover the many benefits of doing business in Sweet Home Alabama's aerospace cluster."

"Our workforce and our community are ready to deliver for Blue Origin, an innovative commercial space company that is changing what we think is possible in space," said Huntsville Mayor Tommy Battle. "These BE-4 engines will power launch systems to put everything from satellites and products into orbit to space tourists and perhaps even space settlers into the final frontier. You truly can't get to space and explore all of its untold promise without going through Huntsville first."

"Today's groundbreaking by Blue Origin celebrates a valued and continued partnership in Madison County and the Rocket City," said Madison County Commission Chairman Dale W. Strong. "Blue Origin recognizes both the strength of local aerospace engineering expertise, and also values the remarkable skill of our advanced manufacturing and workforce capabilities. We're looking forward to Blue Origin writing a new chapter in our history of propulsion capability in north Alabama." ■



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BRITE constellation detects and observes complete Nova Cycle

Nanosatellites developed using technology from Canada's Space Flight Laboratory (SFL) have detected a classical nova more than 1,000 light years from Earth and observed its entire outbreak cycle over a period of 150 days, an unprecedented achievement for space telescopes, especially on satellites of this size.

The 7-kg nanosatellites, each about the size of a toaster, are part of the five-satellite BRITE (BRiGht Target Explorer) mission launched over a two-year period, 2013-2014, by Canada, Austria and Poland. Two BRITE satellites detected the nova outburst with their onboard optical telescopes in the Carina constellation on March 22, 2018. For the next five months, they observed the full life-cycle of the nova from initial outbreak, through rapid increase in brightness, to gradual fading and return to dwarf status.

The temporal resolution and precision of the nova observation were unprecedented, according to BRITE researchers. The phenomenon has been named Nova Carinae.

The BRITE mission was conceived and developed with the goal of proving that serious space astronomy could be conducted cost effectively with small satellites using advanced attitude control and accurate pointing technologies developed by Space Flight Laboratory (SFL). Established in 1998 as a self-sustaining specialty lab at the University of Toronto Institute for Aerospace Studies (UTIAS), SFL has built more than 20 nano- and microsatellites with over 90 cumulative years of successful operation in orbit at the time of writing.

"Smaller satellites were once thought of as toys because their masses were too low to achieve the stability in orbit that enables complex applications in Earth observation, space astronomy and other scientific research," said SFL Director Dr. Robert E. Zee. "Today, these microspace missions are a reality, and they are far more cost effective than traditional satellites."

The attitude control technologies developed by SFL have made it possible for nano- and microsatellites to remain stable in orbit and point precisely at objects – either on the Earth or in outer space – for prolonged periods. As was the case with Nova Carinae, the BRITE satellites point their telescopes at specific constellations for up to six months at a time.

"Nanosatellites had never been used for space astronomy, but because of the BRITE mission, people are now saying this is the way to go," said Prof. Anthony Moffat, a BRITE researcher at the Center for Research in Astrophysics of Quebec (CRAQ). "[Smaller satellites] are inexpensive, and you can do good science with them."

SFL's attitude control technologies have also been applied successfully in several Earth observation programs as well, including the 2016 GHGSat-D demonstration microsatellite mission. Designed to demonstrate that point sources of greenhouse gas emissions on the ground could be monitored from space, GHGSat-D proved so successful that GHGSat Inc. of Montreal has awarded the development contract for two commercial microsatellites to SFL.

"We have continued to fine tune the attitude control and satellite pointing technologies," said SFL's Zee. "In the 11 microsatellites now under development at SFL, we are building satellites that surpass the capability of the BRITE nanosatellites launched just a few years ago." ■

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IN BRIEF...



UK based Sky and Space Global Ltd has been nominated for the prestigious Global Mobile Awards 2019 (GLOMO Awards), with winners to be announced at the Mobile World Congress held annually in Barcelona. The company is in the process of deploying 200 highly sophisticated nano-satellites above the Equatorial Belt. The congress is being held this year on February 25-28. SAS was one of the five nominees shortlisted for an award in the category "Best Mobile Innovation for Emerging Markets", along with Huawei, Lumos, Mavenir and Yego Innovation.



Blue Origin demonstrated the versatility of the New Shepard system by taking 8 NASA-sponsored research and technology payloads into space. This flight was dedicated to NASA's Flight Opportunities program, an essential program for researchers providing access to microgravity for technology development. Blue supports NASA's Flight Opportunities program and its role in perfecting technology for a future human presence in space.



With the civil works underway at the first Australian Ground Network site near Geraldton in Western Australia (AGN-W), Capricorn Space CEO Mark Thompson has announced that CGC Systems has been contracted to supply and install the first antenna systems on site. Mark said, "I am pleased to announce that we have recently signed a contract with CGC Systems of Basingstoke, UK to supply and install two 5 meter S/X-band antenna systems at our AGN-W site. This contract award followed an extensive industry wide engagement and formal tender process during the second half of 2018 and this contract award is in line with our program timeline of offering commercial services by mid-2019".



The Satellite Applications Catapult and Infostellar have signed a memorandum of understanding (MoU) to provide UK businesses with enhanced access to the Satellite Applications Catapult's ground station in Goonhilly, Cornwall.

The Catapult's ground station is the primary ground location for its In Orbit Demonstration (IOD) programme – a unique service which supports UK business to achieve the launch of satellite data services.

Radar analyzes deorbiting systems

Deorbiting Systems are to ensure less debris and more safety for satellites in space. Integrated into the space systems, these should allow them to crash deliberately after their mission ends. The commitment of the space operators to these measures and thus the associated technologies are still relatively young. With the space observation radar TIRA, the Fraunhofer FHR supports manufacturers and operators with analyzes of the systems in use, as such, providing important information on their correct function and how they can be further optimized for their important task. Their space radars TIRA and GESTRA presented researchers with examples of their use at the ESA Neo and Debris Detection Conference from 22 to 24 January 2019, in Darmstadt.

With the unfolding of two novel, passive deorbiting sails, designed to function as brake sails, the French space agency CNES marked the end of the mission of their satellite Microscope in the fall of 2018. They bring the satellite to an orbit approaching the Earth so that it will burn up in the earth's atmosphere in 25 years. The space operators have voluntarily committed themselves to these actions, as remnants of past space missions increasingly threaten our space based infrastructure for communications, navigation and much more. Even a collision with a particle only one centimetre in size can seriously damage or destroy an active satellite. More sustainability in space is needed.

Gradually, the first deorbiting systems are being used. These technologies are still relatively young, and ensuring proper functioning is for manufacturers and aerospace organizations all the more important. It could be done by elements like cameras on the satellite itself. However, this causes high additional costs and carries a certain risk, as these sensors have to function properly maintenance-free during their complete life and deorbiting period. With the space observation radar TIRA, the scientists of the Fraunhofer FHR can provide space operators with reliable support from the ground in their analysis of the systems at any time. With the CNES satellite Microscope, TIRA was able to measure to within a few centimetres that both 4.5-metre-long deorbiting sails had fully unfolded and aligned at the correct angle to the satellite. Together with the pressure sensors mounted by CNES on the satellite itself, the first success of this deorbiting system was celebrated. In further measurements, TIRA will investigate whether the sails will remain stable and reduce the orbit of the satellite.

Even if there is no longer any contact with the space system, the Fraunhofer FHR is helping with ever-finer methods of analyzing malfunctions and creating reentry forecasts for decommissioned or uncontrolled space systems, such as the Chinese space station Tiangong-1 that crashed in the spring of 2018. At the ESA Neo and Debris Detection Conference in Darmstadt from 22 to 24 January 2019, the researchers presented their complementary space observation radars TIRA and GESTRA both in the exhibition and in the lecture sessions. On 24 January 2019 Dr. Sommer presented the self-rotation analyzes of Tiangong-1 which were important for the entry forecasts of the Chinese space station. ■

PolyU provides multi-disciplinary support to the nation's historic landing on the far side of the Moon

The Hong Kong Polytechnic University (PolyU) proudly supported the nation's current lunar exploration, Chang'e-4 lunar probe, which successfully performed the historic landing on the far side of the Moon on 3 January 2019. Adopted by Chang'e-4 mission was PolyU's advanced technologies, namely the design and development of an advanced Camera Pointing System, and an innovative lunar topographic mapping and geomorphological analysis technique in landing site characterisation for the space craft.

"PolyU is very honoured to be involved in and to make contributions to the nation's lunar missions, in particular in this debut landing on the far side of the Moon, the first-ever in the history of mankind," said Professor Alex WAI, Vice President (Research Development), PolyU. "PolyU attaches great importance to the mission and mobilises multi-disciplinary resources to ensure the deliverables meet the stringent requirements of a space mission."

For the first lunar mission in the world to land a space craft on the far side of the Moon, the selection of a safe

landing site with scientific value is of paramount importance. Dr Bo WU, Associate Professor of Poly's Department of Land Surveying and Geo-Informatics, has led a team to conduct a research titled "Chang'e-4 Landing Site - Topographic and Geomorphological Characterisation and Analysis" since March 2016.

Funded by the China Academy of Space Technology (CAST), the team amassed a large amount of lunar remote sensing data from multi-sources to create high-precision and high-resolution topographic models for two potential landing regions, one of them is the current Chang'e-4 landing site, the Von Kármán crater inside the South Pole - Aitken basin on the far side of the Moon.

Dr Wu and his team studied two landing regions for Chang'e-4 mission, each covering an area of about 1,500 square kilometres, which is 1.4 times of the total area of Hong Kong.

They analysed in detail the terrain slopes, terrain occlusions to sun illumination and telecommunication, crater distribution, rock abundance, and geological history of the region. These analyses helped the team to put forward a sound and evidenced-based proposal of possible landing sites. ■

A space-based gold rush

Ask someone about deep space mining ten years ago, and people would have looked at you with incredulity. Today, however, we're seeing the first companies pop into existence with just that in mind, while governments and associations the world over begin the onerous process of working out the legalities.

Deep space mining is a very modern solution to the old problem of resource depletion here on Earth. Whether we'll see successful space mining in our lifetimes – i.e. the cost-effective extraction of valuable elements from space, delivered back to Earth or else utilised in space – is yet to be established. There are several factors at play, and it's vital that we work out the financial, legal, technical, ethical matters ahead of any missions.

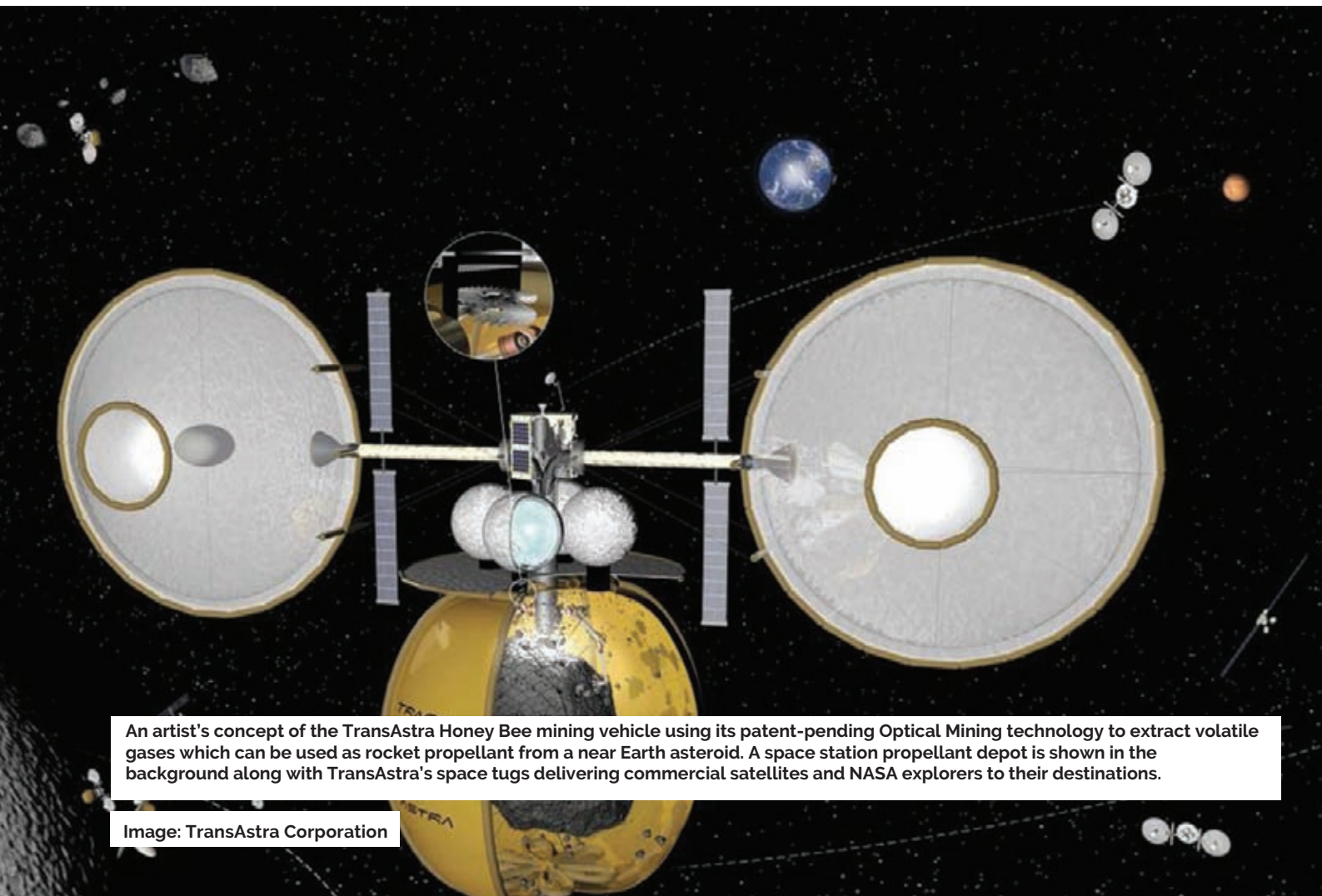
Cost is absolutely going to be a limiting factor. There's the development cost of spacecraft and suitable mining equipment, the cost to launch, costs related to telemetry and control, both in man-hours and more equipment, and the biggest cost of all: Returning mined materials to Earth (or perhaps an off-world base).

Then there's the legal implications. Deep space mining is covered by the Outer Space Treaty, which states that 'outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.' Indeed, the treaty allows for private property rights and exclusive ownership rights over natural outer space resources if removed from their natural place. In addition, some countries are launching

their own acts. The 'SPACE Act of 2015' facilitates private development of space resources consistent with US international treaty obligations by recognising the right of US citizens to own space resources they obtain. Later in 2017, the Government of Luxembourg became the first European country to pass a law conferring to companies the ownership of any resource they extract from space.

Technologically-speaking, we've still a long way to go before we can successfully mine asteroids for anything. While a small number of missions have landed on ore-rich asteroids, the technology required to mine and refine materials from a moving asteroid, while maintaining (or creating from water) adequate fuel supplies to return those materials to Earth, remains beyond our reach. The alternatives to transportation back to Earth include transport to a nearby off-world base, or else utilising those mined materials in space, also require heavy technical development prior to becoming reality.

And then there's the ethics of it all. Just because we're depleting the resources naturally available on Earth, does that give us the right to mine other celestial bodies



An artist's concept of the TransAstra Honey Bee mining vehicle using its patent-pending Optical Mining technology to extract volatile gases which can be used as rocket propellant from a near Earth asteroid. A space station propellant depot is shown in the background along with TransAstra's space tugs delivering commercial satellites and NASA explorers to their destinations.

Image: TransAstra Corporation

for these precious materials?

Party balloons will be the death of us all

Resources here on Earth are finite, and we're fast running out of vital elements. Helium is one such element that us Chemists like to remind people about; it's vital for the operation of MRI scanners, cryogenics and NMR spectrometers, but it's relatively scarce on Earth, although there have been recent discoveries of new sources bringing us to around a 117-year supply. Despite this scarcity, helium is still freely available on the high street for filling balloons, something many scientists have taken umbrage with.

"I will not be happy if I cannot have a medical scan in my 70s, because we wasted helium on party balloons while I was in my 30s," said David Ward of the Culham Centre for Fusion Energy.

The second-most abundant element in the universe never reaches the Earth via solar winds because of our strong atmosphere, so there is no chance of natural replenishment. However, rocks brought back to Earth from the Moon contain around 22g of helium per cubic metre. "There is also hydrogen in that soil, which astronauts could use for fuel and to make water, so you could envisage the day when it becomes economic to build mines on the Moon to supply us with helium. It just depends how expensive our own sources become," Ian Crawford from Birkbeck College, University of London, told The Guardian.

Of course, it's not just helium. Other elements such as copper, phosphorus, iridium, palladium, platinum, rhenium, ruthenium, gold, silver, iron, cobalt, tungsten,

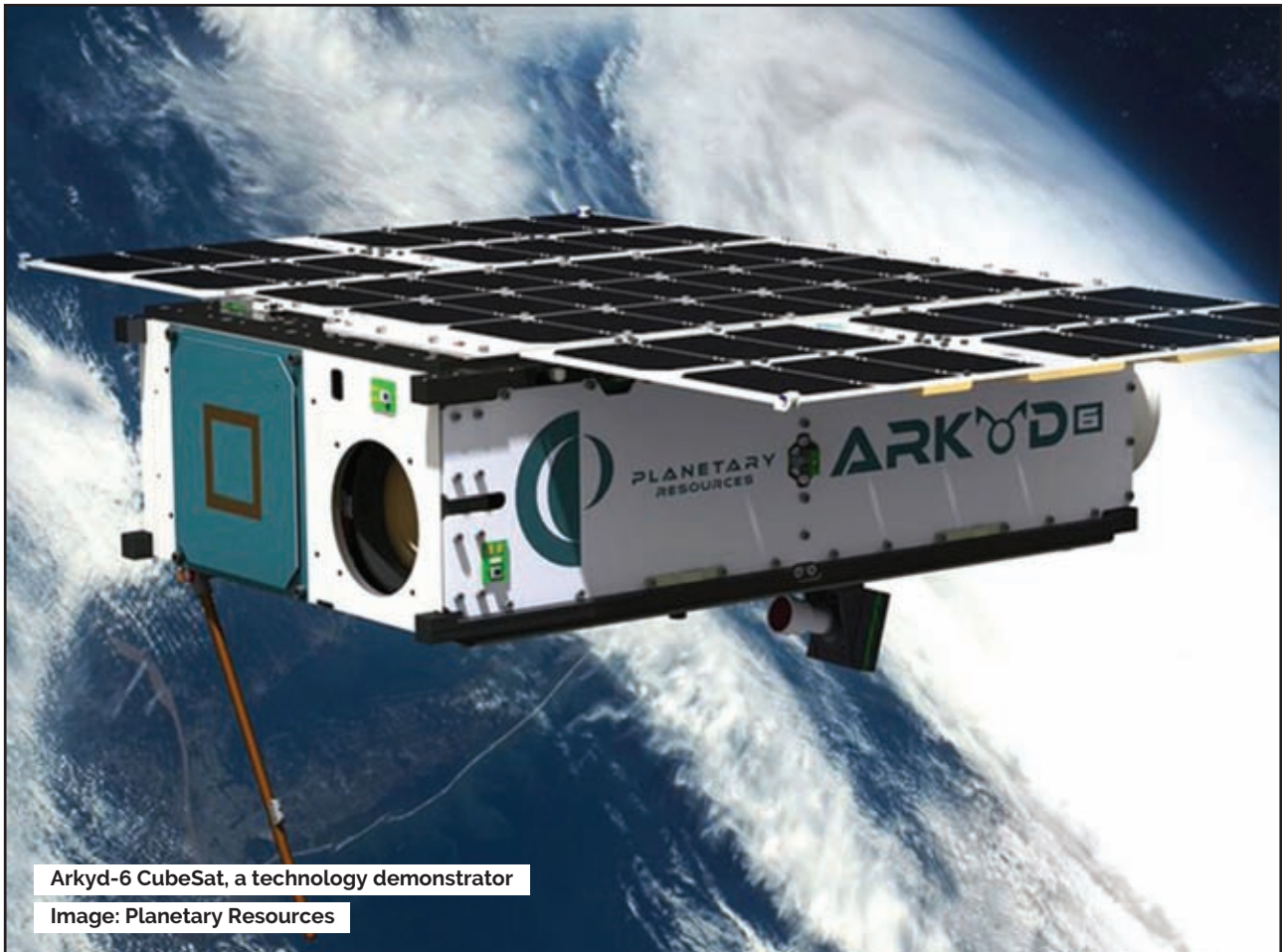
manganese, molybdenum, nickel, aluminium and titanium, are vital for modern life applications like medicine, construction, electronics, etc., are extremely limited on Earth, and far more freely available in space.

Who's getting in on the action?

Considering the high financial barrier to entry, there are quite a large number of companies getting in on the deep space mining game right now.

Planetary Resources' goal is to be a leading provider of resources for people and products in space by identifying, extracting and refining resources from near-Earth asteroids. As a first step, the company is seeking to identify and unlock asteroids with critical water resources, which are used for both life support and refinement into rocket propellant, necessary for human expansion in space.

In January 2018, the company launched the Arkyd-6 CubeSat, a technology demonstrator designed to detect water resources in space. The Arkyd-6, which is fully-autonomous but communicates with Earth at every critical checkpoint, successfully demonstrated its distributed computing system, communications, attitude control system, power generation and storage with deployable solar and batteries, star tracker and reaction wheels, and the first commercial mid-wave infrared (MWIR) imager operated in space. The MWIR broadband imager spans 3-5 microns within the IR region, which is sensitive to the presence of water and thermal energy. During the mission, the MWIR was used to find the presence of water on Earth. The data obtained from this mission will be used in the development of the Arkyd-



Arkyd-6 CubeSat, a technology demonstrator

Image: Planetary Resources

Moon Express Lander One

Image: Moon Express

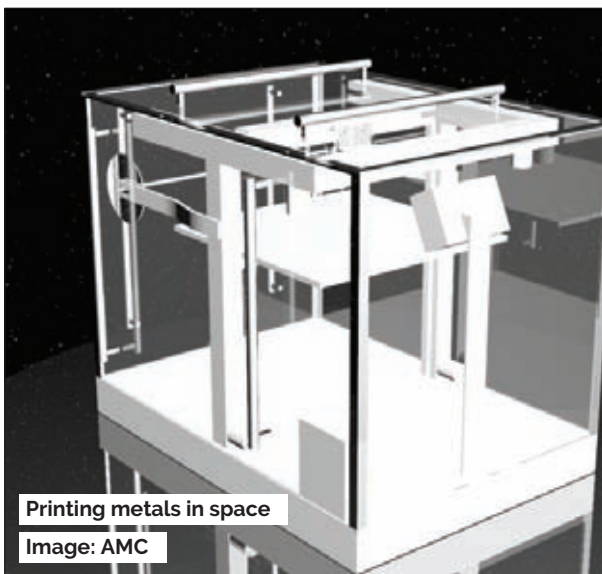
**Printing metals in space**

Image: AMC

301, Planetary Resources' next platform.

Once the company has its technology refined, it will deploy multiple spacecraft via a single rocket launch to pre-determined asteroids to collect data and material samples. Data collection will include global hydration mapping and subsurface extraction demonstrations to determine the quantity of water and the value of the resources available. The information gathered will allow Planetary Resources to design, construct and deploy the first commercial mine in space.

Deep Space Industries (DSI) is, alongside Planetary Resources, the other big name in deep space mining. The company plans to build a new type of spacecraft that drives down the cost of access to deep space, as much as 50 times lower than today's solutions. According to DSI, its spacecraft will grant private companies and government agencies access to high Earth orbits, Lunar orbits, near-Earth asteroids, Venus and Mars, helping unlock the commercial opportunities of space.

DSI has already developed the Comet system, a cost-effective electrothermal propulsion system for CubeSats and microsatellites that uses water as a propellant, available for sale for a unit price of US\$200,000. Astro

Digital and BlackSky have already signed deals to acquire several of the Comet systems from DSI. The next focus is the Xplorer spacecraft, a 12U CubeSat which is designed to use its own propulsion system to move from low Earth orbit (LEO) to an Earth departure trajectory. Xplorer is expected to become available in 2020.

Most recently, DSI closed the first tranche of its Series A funding round, having raised more than US\$3.5 million from private investors. The funding will be used to continue the development of Xplorer and help develop the new launch-safe bipropellant rocket engine dubbed Meteor.

Moon Express is another major player in off-world resource acquisition, but with a focus primarily on the Moon, rather than the asteroids other companies are looking into. Moon Express aims to extract resources available near the surface of the Moon, including valuable minerals and water for human life support and conversion to rocket fuel. With a family of innovative robotic exploration spacecraft, Moon Express plan regular flights to the Moon from 2020.

The first mission, Lunar Scout, will demonstrate the cost-effectiveness of entrepreneurial approaches to space exploration, carrying a diverse manifest of payloads including the International Lunar Observatory 'MoonLight' from the IFN National Laboratories of Frascati and the University of Maryland, and a Celestis memorial flight. The second mission, Lunar Outpost, will enable the first commercial presence and exploration of the lunar South Pole. The poles of the Moon have concentrations of water and other valuable resources, as well as 'peaks of eternal light' where nearly continuous sunshine and direct communication with Earth are possible. The primary goals of this mission are to set up the first lunar research outpost, prospect for water and useful minerals, and accommodate a variety of research instruments for our expedition partners. The third mission, Harvest Moon, expected to take place by 2020, includes the first commercial sample return mission, which also begins the business phase of lunar resource prospecting.

In recent news, October 2018 saw Moon Express sign a Memorandum of Understanding (MoU) with the Canadian Space Agency (CSA) to explore options for collaboration. Under the agreement, the CSA and Moon Express will explore the possibilities of using the Moon Express lunar orbiter and lander systems for potential CSA payloads and will promote possibilities for collaboration between Moon Express and the Canadian space industry and academia.

Asteroid Mining Corporation (AMC) is one of the newest companies in deep space mining, having been founded in the UK in 2016 in order to 'advance the march of human progress and civilisation by bringing the world the Third Industrial Revolution: Moving as many polluting industries into space and out of Earth's fragile biosphere as possible so that the Earth can become the garden of the Solar System.' The company aims to build the infrastructure to support a space-based population and space-based economy, which will of course require the extraction of deep space resources.

AMC has three objectives in its short-term plan. The first is to conduct robotic operations in space via the development of a small satellite dubbed ASP1, a 6U spectroscopy space telescope, which will gather spectrographic data on target asteroids that will be

made commercially-available. Indeed, in July 2018, it emerged that AMC is seeking UK£2.3 million to build a satellite capable of identifying platinum-group metal deposits on near-Earth asteroids, namely ASP1. The second objective is the development of an additive manufacturing system for printing metals in space, which will enable the production of structural and component elements for orbital installations. The third is the production of a probe that can intercept an asteroid and excavate a volume of material.

TransAstra Corporation's vision is somewhat similar to AMC's, namely for humanity to 'become a spacefaring species homesteading the solar system.' The company would see thousands of asteroids transformed into refuelling stations for NASA (the NASA Emerging Space Office awarded the company a grant to study the economic impact of asteroid in-situ resource utilisation – ISRU) and commercial spacecraft and plans to lead the work in supplying services for asteroid mining, space solar power, space tourism and space-based manufacturing. While little information is available on its own website, TransAstra's Chief Technology Officer Joel Sercel produced a directorate published by NASA spelling out plans for Optical Mining of asteroids, which will reportedly provide affordable mission consumables and radiation shielding. In Optical Mining, excavating and processing asteroid materials is accomplished by highly-concentrated sunlight, which TransAstra has shown can be used to drill holes, excavate, disrupt, and shape an asteroid while the asteroid is enclosed in a containment bag.

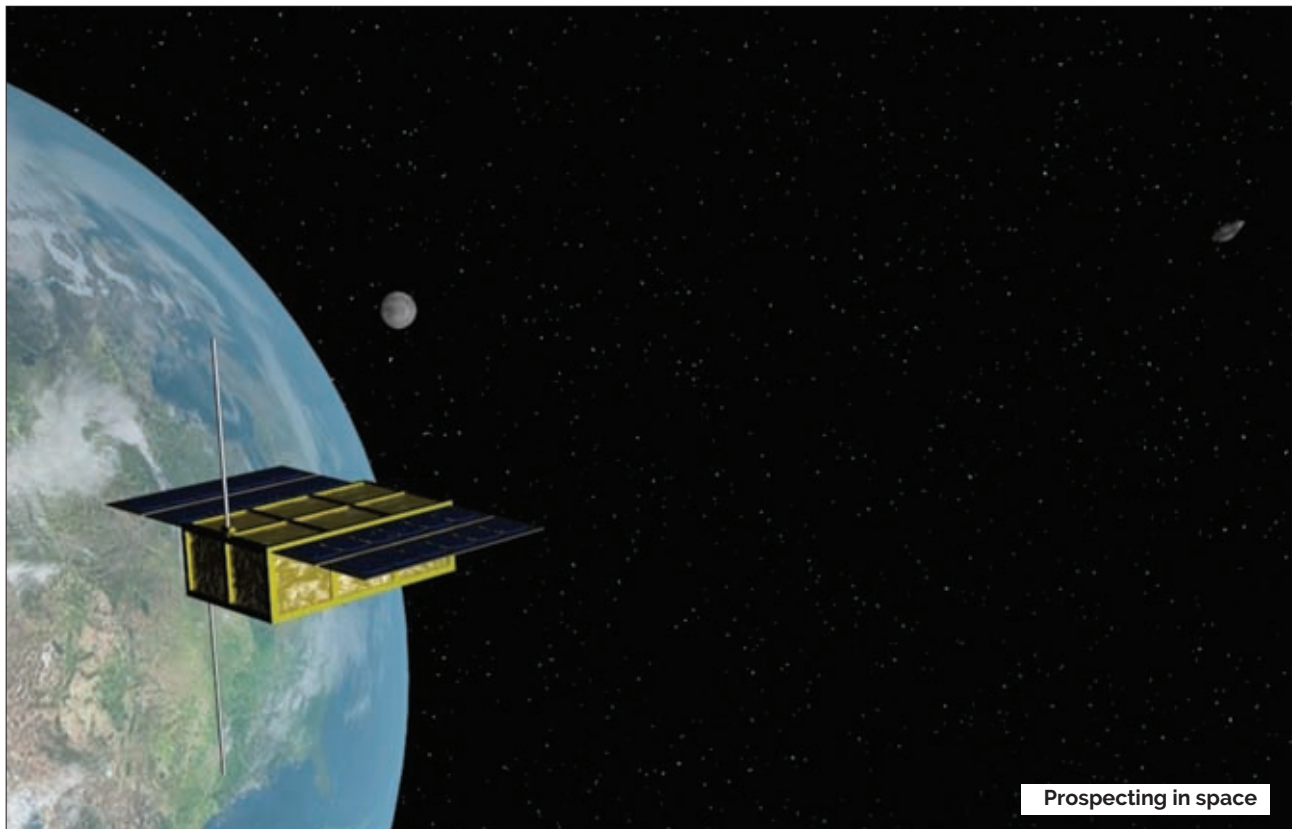
During its Phase 1 work, the company demonstrated Optical Mining in the laboratory and performed mission and systems analysis of the application of Optical Mining to human exploration missions. Mission analysis showed that the most accessible Near-Earth Objects (NEOs) can be used to provide mission consumables for human

exploration in deep space with the potential of saving up to US\$10 billion per year. Phase 1 technical work included a full scale 8kW Optical Mining demonstration using a high-fidelity CI-type asteroid simulant in vacuum using sunlight from a 10m diameter solar concentrator without mechanical contact or downforce.

Moving onto Phase 2, TransAstra will complete mission and system analysis of the application of Optical Mining to an exciting program of human exploration and we will mature the technology of Optical Mining to the point at which NASA can baseline this approach for an affordable program of human exploration. Mission studies will address the production via Optical Mining missions to extract and retrieve resources, consumable processing, storage, and application of consumables to human exploration mission in cislunar, NEO and Martian space. The mission studies will be tightly coupled with laboratory work, which will include the development and integration of a 30kW Optical Mining test apparatus and integration with a high-quality vacuum chamber for a test program involving Optical Mining.

The next gold rush?

Deep space mining is an expensive game, and it certainly won't be the free-for-all 19th Century gold rush we experienced in Australia, New Zealand, South Africa, Canada and the USA. But that doesn't mean there aren't big bucks to be made, for those bold enough to reach. There's a lot still to be achieved, particularly on the technological side, but there's a lot of opportunity too. Noted experts like Neil deGrasse Tyson certainly seem to think so: "The first trillionaire there will ever be is the person who exploits the natural resources on asteroids," said Tyson. "There's this vast universe of limitless energy and limitless resources. I look at wars fought over access to resources. That could be a thing of the past, once space becomes our backyard." ■



Prospecting in space

Delivering value in near and deep space

Goonhilly Earth Station Ltd acquired the Goonhilly satellite station in Cornwall, UK, from BT back in 2014, in order to realise the huge potential of the site. Plans for a multi-faceted space hub will see the firm forging ahead with a number of commercial and scientific endeavours. Ian Jones, CEO of Goonhilly Earth Station Ltd, talks about the future of Goonhilly Earth Station, and its role within the NewSpace sector.

Question: Goonhilly Earth Station was only acquired relatively recently by Goonhilly Earth Station Ltd. What can you tell us about the company's capabilities and expertise?

Ian Jones: Our background is first in designing specialist communications equipment for Earth stations and spacecraft, and second, in operating them. Our staff have a wealth of experience in space systems and communications systems engineering. The first opportunity to operate our own ground station came a few years before we even considered Goonhilly as a potential base. On that occasion (in a previous company), we set up an antenna in our office car park, kept the margins as low as possible and beat BT to win a satellite service contract. This gave us a taste for Earth station operations – and also showed us that the business was mature and highly competitive.

When I heard that Goonhilly was going to be closed, this previous experience made me think that the commercial teleport market might be too difficult, but that the antennas could be re-purposed for radio astronomy and deep space communications – an interesting and growing market. We looked at all the potential revenue streams that Goonhilly could support and realised that the site was a hidden gem – provided that these inter-related revenue streams could be opened up. We also realised that the space communication industry was changing, and we had the skills required to play a vital role. We received a lot of



Ian Jones, CEO, Goonhilly Earth Station

Image: Goonhilly Earth Station

unprecedented fibre connectivity, on-site power generation and a wide range of buildings, labs and offices underpin the business. They provide our experienced and energetic team with the strong foundations required to create exciting, world-leading projects. Because of our background in designing and manufacturing complex space communication systems, we understand the operations of a teleport and what's required from both the customer point of view and the systems engineering perspective. We immediately decided to focus on the more specialised and difficult parts of the market – such as telemetry, tracking and command (TT&C), deep space communications and low Earth orbit (LEO) tracking – and that's been our forte ever since.

Where there are difficult engineering processes that are only entrusted to teams with a lot of expertise, we've proved ourselves time and again, picking up contracts with all the big satellite operators: SES, Inmarsat, Eutelsat, Intelsat and Hughes. For example, they trust us to provide the vital communications required to fly and guide their satellites. That's been our unique selling point to date.

Question: Back in May 2018, Peter Hargreaves, the billionaire founder of the investment services company Hargreaves Lansdown announced he had invested UK£24 million into Goonhilly Earth Station. What can you tell us about this, and the opportunities it will bring?

Ian Jones: Our previous investor, Downing, enabled us to buy the Goonhilly site and get some early wins under our belt. It was a great relationship that kick-started the new business. However, the investment vehicle was a Venture Capital Trust (VCT) scheme with a five-year fixed window. We wanted to find an investor with a longer-term view who would help us scale up

the business, so we actively looked for a high-net-worth investor who shared our vision.

From the start, Peter Hargreaves' philosophy has been to provide us with the liquidity needed to realise a bold growth target. With the funding secured, we have

Where there are difficult engineering processes that are only entrusted to teams with a lot of expertise, we've proved ourselves time and again, picking up contracts with all the big satellite operators

opposition for including radio astronomy in our plans, but we knew that the techniques involved would unlock the communication systems of the future.

The opportunities afforded by owning and operating Goonhilly are compelling: The fixed assets including large antennas, a secure site, proximity to

embarked on an ambitious business plan, which will see us open facilities in various parts of the world as part of our plan to build a truly global business. For example, over the last few months we have opened offices in Farnborough in the UK and in Australia.

Question: We understand that Goonhilly Earth Station has released a new roadmap which will galvanise its position in the satellite industry and NewSpace economy of the future. Can you take us through the key points?

Ian Jones: There are four main areas in our roadmap.

Our first growth area is *deep space*; namely, everything beyond geostationary orbit. We're planning to build a global network of deep space antennas. We've already started upgrading antennas at Goonhilly, and are actively looking at sites to build capabilities in Australia. We'll also be looking for sites in Northern America in the future.

The second area we're looking at is *near space*, so everything from geostationary orbit downwards. This will focus on the traditional GEO satellite market, where Goonhilly has always played a key role, but we're also interested in building capabilities that support other orbit configurations, especially LEO, for which we already host tracking antennas for a few customers. We are looking at how we can get into that market more broadly. We're developing a few different partnerships, but I think it's a business model that hasn't quite been fully bottomed in terms of how the market will actually work. To support a constellation of LEO satellites, you almost need a constellation of tracking antennas on the ground, and that's a difficult business model. We feel that we're the right size company, we're hungry, growing and capable of being disruptive in that market.

The third part of our roadmap is that Goonhilly, by nature of its geographic location, is at the end of many sub-sea cables which connect to the UK via Cornwall. We also have very good terrestrial fibre connectivity back to London, as well as lots of space and redundant power supplies. It's a great location for collecting and servicing data. We're investing approximately £1 million in a brand-new data centre facility to bring together the world's sub-sea cables, create an Internet exchange at Goonhilly, and have that link between terrestrial, sub-sea cable and satellite.

The fourth area we're exploring, because of our heritage and background in design engineering, is system design - particularly software defined radio and smart antenna systems - that can be built in medium to large scale for supporting ground terminals.

Our new office in Farnborough will lead the charge here, housing our design and engineering teams. We are actively recruiting more talented engineers to get

involved with these exciting projects. We're particularly looking at phased arrays - being able to connect lots of antennas together using electronics so they can beam-form and be steered electronically. This is particularly important as the constellations of orbiting satellites start to come into play.

We work closely with a group of universities, including Oxford, Manchester, Leeds and Hertfordshire, and we have proposals to create a factory facility at Goonhilly working with those universities. That programme is coming together very quickly too.

Question: The NewSpace sector is the place to be right now, with mega-constellations, small satellites, reusable launchers and off-world settlements all a key focus. What's your take on the NewSpace movement, and the opportunities available for businesses?

Ian Jones: The whole space industry started off with the superpower nations, followed by international



organisations like Intelsat and Inmarsat. When they were established, they were international collaborations between nations; they were later privatised, and the status quo prevailed for decades. The only people able to get into space were the people with multi-hundred million-dollar budgets. In parallel, from the late 1980s/early 1990s, smaller companies like Surrey Satellites have been slowly piggy-backing on launches; this model of smaller companies gaining access to space has taken hold, but it has taken a long time to prove itself.

Today, organisations like SpaceX are significantly lowering the cost of getting into space, and are publishing their prices too. This is really significant, because entrepreneurial companies can go to investors and say: "This is the cost of getting into space," rather than it being an open-ended unknown. It's changed the whole paradigm. Now we have disruptive companies like Planet, who have been able to go out and get funding for constellations with all the costs known up front.

In the past, a 1:1 ratio of rocket launch to payload launch was typical. Today companies like Planet are tearing up the rule book, ushering in an era of multiple

payload launches from a single rocket. Up until now, the aim of the game was to get a large mass into (usually) equatorial orbit, which meant utilising big rockets from launch near the equator. But if you're going to have a constellation, you need to be in a roughly polar orbit. And you need to get a small mass, very frequently, into orbit. This dramatically changes the whole launch dynamic and opens up a wealth of opportunities.

The whole idea of the UK getting its own launch facilities is very interesting and marks another milestone in the burgeoning new space sector. Here at Goonhilly, we're very excited to be involved with Spaceport Cornwall's plans to provide Virgin Orbit with a strategic Western European location at Newquay for horizontal launches. We will provide the all-important tracking services for this new venture.

Question: Goonhilly Earth station is reportedly involved in several exciting new off-world projects, from the ESA's Commercial Lunar Mission Support Services, the Lunar Pathfinder programme, through to the world's first deep-space communications system. Can you provide an update on these projects?

Ian Jones: Goonhilly and Surrey Satellite Technology (SSTL) signed a collaboration agreement with the European Space Agency (ESA) for Commercial Lunar Mission Support Services back in April 2018. This commercial partnership aims to develop a European lunar telecommunications and navigation infrastructure, including the delivery of payloads and nanosats to lunar orbit.

What's unique here is that we did not ask for funding from ESA; instead these missions will be funded by payload customers wanting to take a piggy-back ride to the Moon on the Lunar Pathfinder spacecraft. ESA really likes our entrepreneurial thinking and the fact that

we will be addressing a real gap in the market for commercial endeavours.

We've already succeeded in getting quite a few payload commitments from customers for the first flight and are now working on getting commitments to fulfil our payload quota and make it a commercially viable mission.

In parallel, ESA promoted a competition to send missions to the Moon. Several missions were selected, which should get funding approval at the next ESA ministerial meeting. Once that happens, the partners will start building the hardware - including the Lunar Pathfinder spacecraft.

Last but not least, we've also won a £8.4 million contract with ESA to upgrade Goonhilly 6, our 32m antenna, to make it fully compatible with the Deep Space Network. It will then become one of ESA's deep space nodes.

Question: What are your expectations for Goonhilly Earth Station in 2019 and beyond?

Ian Jones: We want to be an industry disruptor and believe we are really well placed to realise this vision. We have funding in place, we are profitable, and we are already on a strong growth trajectory.

At the start of 2018, we had 20 people, and by October we were up to 33 - and counting. We expect headcount to double during 2019 as we ramp up our activities in our four key areas.

The key now is to hire talented people who are enthusiastic and passionate about working for Goonhilly and helping to shape the next wave of satellite communications.

At the end of the day, space exploration is of little value unless you can get the data back down to the ground. And that is Goonhilly's sweet spot. ■



Image: Goonhilly Earth Station



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Touring the universe

Space is the stuff of dreams – Anyone in the world can look up at night, and there it is, always present, and always out of reach. The distance between human kind and space is shrinking, however, as space tourism edges ever-nearer reality.

Back in the 20th Century, tourism of any kind was extremely limited. For most families, tourism described that one week a year where entire families would decamp to relatives living somewhere else in the country, or a week in a B&B by the seaside or camping in a rickety old tent in Cornwall. As time has passed, tourism has changed; air travel costs have plummeted, making individuals and families much more likely to be jetting off to destinations abroad. Multiple foreign holidays a year are not unusual anymore, to cost-effective destinations in France, Spain, Turkey, etc., where money stretches further, and the change of pace can uplift spirits.

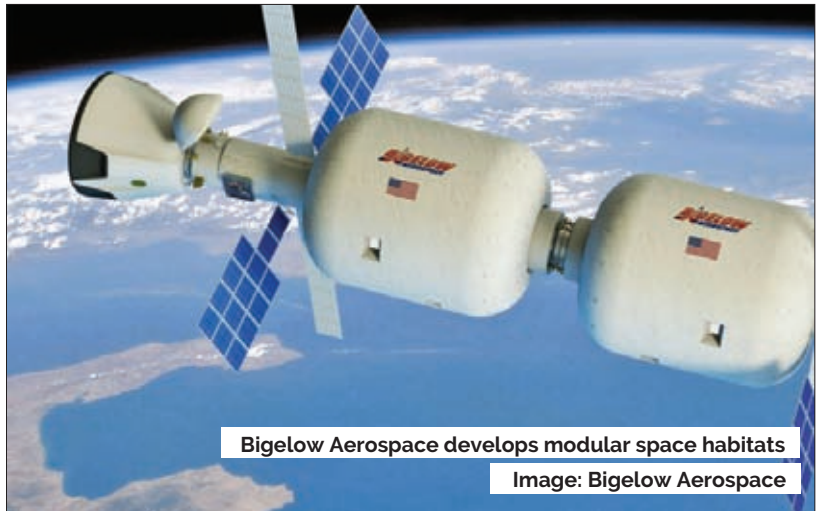
Space tourism, however, has remained largely out of reach, much to the dismay of science fiction fans everywhere. The different types of space tourism – orbital, suborbital, lunar and Martian – have captured the imagination of many. While we're not quite there yet, work continues on the development of space tourism programmes, and soon we may see the beginning of a (not entirely) new industry.

Space tourism in the 2000s

Space tourism is not a new endeavour by any means. It's actually already been demonstrated, albeit on a very small scale, some years ago.

Space Adventures, founded in 1998 by Eric C Anderson, has already sent seven non-government astronauts into space on eight successful missions (one astronaut flew two missions). During 2001-2009, these tourists (see below) were flown to the International Space Station (ISS) on board Russian Soyuz spacecraft. Several made deals with third parties to perform research while on board the ISS. The flights cost a reported US\$20-40 million apiece.

- Dennis Tito: The American businessman was the world's first private space tourist was launched to the ISS in April 2001 as Space Adventures' first client.
- Mark Shuttleworth: Launched in 2002, Shuttleworth spent 10 days in space, and dedicated his flight to educating South African youth and conducting scientific research.
- Gregory Olsen: Another private astronaut who studied the human body's response to the microgravity environment, Olsen was launched in 2005 and maintained contact with high school



Bigelow Aerospace develops modular space habitats

Image: Bigelow Aerospace

students in New York and New Jersey while on board the ISS.

- Anousheh Ansari: Launched in 2006, Ansari was the first female space tourist. Spending eight days on board the ISS, she conducted four experiments with the European Space Agency (ESA), including studying mechanisms behind anaemia.
- Charles Simonyi: Space Adventures' first repeat customer, Simonyi was launched in 2007 and 2009 to advance civilian spaceflight activities.
- Richard Garriott: Launched in 2008, Garriott demonstrated the opportunities for commercial potential in private space exploration during his stay on board the ISS.
- Guy Laliberté: As the first Canadian space tourist, in 2009 Laliberté conducted the first ever artistic and social event from space on board the ISS.

The Space Adventures programme was halted in 2010 when the ISS crew size increased. The launch vehicle seats were therefore reserved for space station crew, rather than becoming available for private sale.

A luxury market

In previous decades, travelling by plane was the preserve of wealthy individuals or important business travellers. Travelling by plane back then was a real feather in the cap for importance. Over the years, flight costs have plummeted – it's now possible to fly between some European destinations for as little as £20 – and uptake has boomed. There are now more air passengers than ever before, and all the prestige of air travel is gone.

With the advent of space tourism, we'll be seeing a new luxury tourism market, one which can only be enjoyed by the one percent (at least at first). According to ReportsnReports, the global space tourism market is expected to grow at a CAGR of 14.34 percent during 2017-2021, presumably starting from a baseline of zero. The addressable market is extremely slim, with more than 99 percent of future space tourists having a net worth greater than US\$5 million. This makes sense when you consider the huge costs expected for private

spaceflight activities; ReportsnReports notes that 'these people are motivated to try out activities that have not been experienced by the common man.' Charming, I'm sure. One key trend to emerge from the upcoming space tourism industry is the inspiration of a new generation of highly-skilled engineers. When the sky is no longer the limit, we can expect to see a boom in rocket scientists.

Although the space tourism market remains in its infancy, there are a surprising number of companies investing heavily. Well-known household names like SpaceX and Virgin Galactic are joined by newcomers and start-ups as the race for commercial spaceflight is on...

Space Adventures moves on from 2000s

Space Adventures is the only entity that has already demonstrated a successful commercial spaceflight programme back in the 2000s. The company wants as many people as possible to experience what is 'like to live in space, orbit the Earth, or travel beyond it. In the next ten years, Space Adventures plans to enable customers to choose between multiple space tourism options, including a variety of vehicles and destinations.

Today, Space Adventures is offering a variety of programmes, including orbital spaceflight missions to the ISS, zero gravity flights, cosmonaut training programmes, spaceflight qualification programmes, circumlunar missions around the Moon, and is taking reservations for future suborbital spacecraft. The company has been notably quiet regarding recent activities, with no updates on bookings or further programme development.

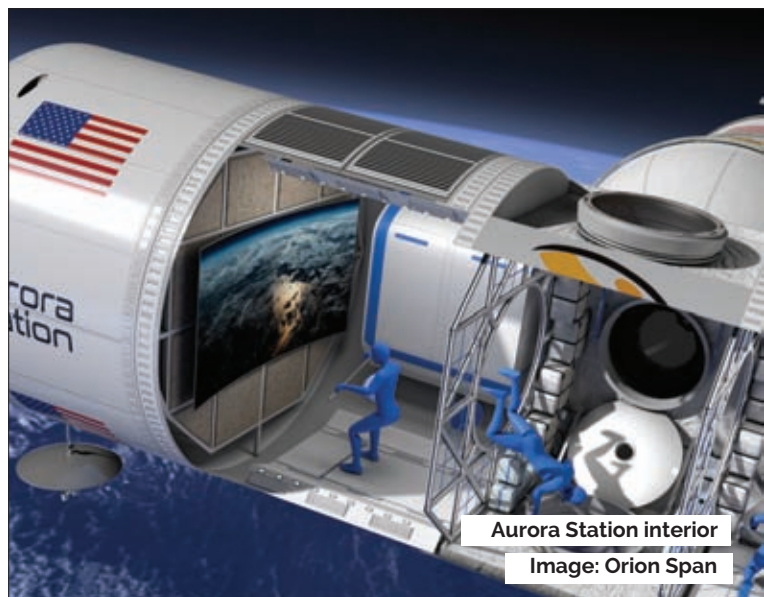
However, in August 2018, Space Adventures was selected by NASA as one of 13 companies to study the future of commercial human spaceflight in low Earth orbit (LEO). The study will inform NASA's strategy for enabling the commercialization of human spaceflight in LEO, and NASA's long-term requirements for the ISS. Space Adventures was due to submit recommendations to NASA on how to quantify the LEO market opportunity, evaluate technical concepts for low-cost habitation, and describe a viable and sustainable business case in LEO, in December 2018.

"We are excited to work with NASA and to have the opportunity to provide input into the future of commercial activities in LEO and thoughtful suggestions on what the agency can do to assist in the development of the marketplace," said Tom Shelley, President of Space Adventures. "When commercial crew vehicles are providing regular access to LEO we will see a great future for space tourism; and we are excited to partner with Made in Space to further understand the in-space manufacturing and the materials processing marketplace."

Roscosmos starts up own space tourism programme

Roscosmos has historically worked with Space Adventures to launch space tourists to the ISS, but it has also recent begun to work on its own independent programme. Now, the agency is developing its own luxury space hotel module for installation on the ISS, in partnership with space station contractor RKK Energia.

Although the full plans have yet to be released, the hotel module will feature four bedrooms, hygiene and medical facilities, and a lounge. According to recent



reports, prices are expected to range from US\$20-60 million for durations of one to four weeks, with a spacewalk accompanied by a professional cosmonaut available for an additional US\$20 million.

Roscosmos plans to launch its space hotel by 2022.

KosmoKurs plans for suborbital space complex

Russia's KosmoKurs is another recent private start-up company exploring space tourism activities. The company announced its plans in 2016, featuring a reusable suborbital space complex (MSCC) consisting of a reusable suborbital rocket (MSRN) and reusable suborbital spacecraft (MSCA).

According to reports, the short-duration missions of around 15 minutes will require a three-day training programme. Passengers will experience 5-6 minutes of weightlessness at 180-220km above the Earth, during which they can freely move inside the 30m³ cabin. The entire package will cost around US\$200,000-250,000 per person. Commercial flights are expected to begin in 2025, although the company faces years of testing first.

Virgin Galactic moves ahead with suborbital spaceflight

Part of Richard Branson's Virgin Group, Virgin Galactic, alongside its sister companies The Spaceship Company and Virgin Orbit, is developing a new generation of reusable space vehicles to open space to everyone. The company's mission is to be the 'Spaceline for Earth.' Virgin Galactic plans to run a regular schedule of spaceflight for private individuals from its operational hub at New Mexico's Spaceport America, the world's first purpose-built commercial spaceport.

Virgin Galactic's spaceflight model consists of a reusable launch system featuring a carrier aircraft, WhiteKnightTwo, and a suborbital spacecraft, SpaceShipTwo. The carrier aircraft climbs to an altitude of around 16km above the Earth, where SpaceShipTwo is released. The spacecraft will be projected to a height of 110km, exceeding the defined boundary of space (100km), reaching a top speed of 2,485mph, and creating a weightless experience for passengers.

Following a shaky start with the inflight loss of SpaceShipTwo VSS Enterprise, Virgin Galactic's first spaceflight vehicle, the future looks promising for the

SpaceShipTwo VSS Unity, which has completed a number of successful test flights since 2014. In May 2018, the VSS Unity achieved its second supersonic rocket powered test flight. The rocket motor burned for the planned 31 seconds and propelled VSS Unity to a speed of Mach 1.9 and an altitude of 114,500ft. The flight advanced Virgin Galactic's understanding of the spaceship's supersonic handling characteristics and control system performance, with vehicle parameters closer to the ultimate commercial configuration. After the flight, VSS Unity's unique re-entry feathering system was deployed for the initial descent.

Meanwhile, December 2018 saw the successful launch of SpaceShipTwo to the 'edge of space' - at 51.4 miles above the Earth - and back again. The ride, which transported two pilots, four NASA payloads and a mannequin, was considered a great success, and the first manned spaceflight launched from US soil since 2011.

In other news, in July 2018, Virgin Galactic signed a framework agreement with Sital and Altec to bring Virgin Galactic spaceflights to Italy. The agreement envisions a dedicated space vehicle system, built by The Spaceship Company, being positioned at the Grottaglie Spaceport, which will integrate significant technological and industrial contribution from Sital and the Italian aerospace industry, pending regulatory approvals. The spacecraft will be utilized by customers like the Italian Space Agency as a platform for high-frequency space research, as well as private individuals to experience space.

"From the Renaissance to modern space science, Italy has always been a natural home to great investors and breakthrough ideas which have shaped the human experience," said Sir Richard Branson, Virgin Group founder. "I believe Italy's vision which has led to this collaboration with our Virgin space companies, will provide a real impetus as we strive to open space for the benefit of life on Earth. This partnership could see Virgin Galactic launch the first person in history into space from Italian soil - and in fact from any European territory. Together, we will help to expand opportunities for science, industry and the millions of people who dream of experiencing space for themselves."

Bigelow Aerospace develops modular space habitats

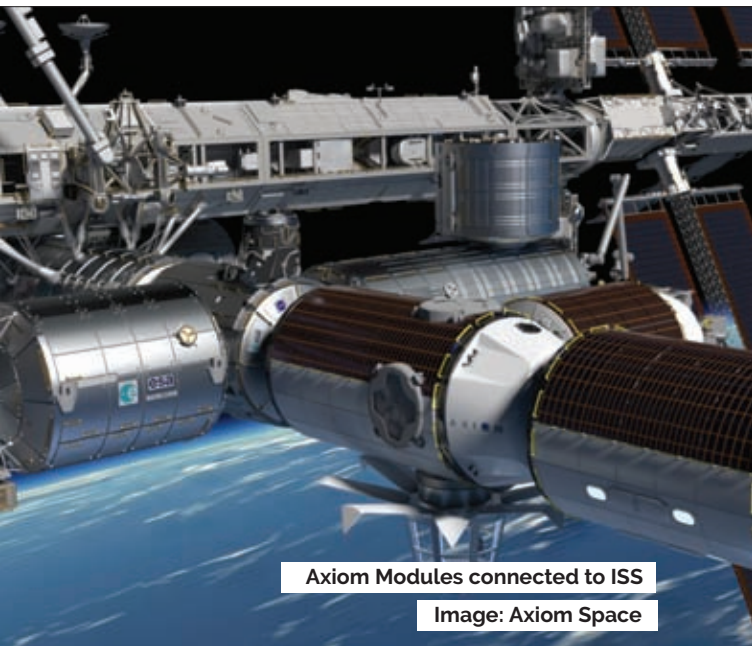
Bigelow Aerospace is a serious contender in the space tourism sector in its own right. Founded in 1998, Bigelow Aerospace develops and manufactures expandable space station modules, and is the only company commercializing NASA expandable module technologies. Bigelow aims to create a modular set of space habitats for creating standalone or expanding existing space stations. The inflatable modules are expected to be more durable than rigid modules due to the use of Vectran, a material twice as strong as Kevlar, and because the flexible walls are theoretically more likely to withstand micrometeoroid impacts better than rigid walls.

Under the Genesis programme, Bigelow has demonstrated the viability of expandable habitat technology in space. Genesis I, Bigelow's first operational spacecraft, was launched into orbit in 2006, while Genesis II was launched in 2007; both remain in orbit today and observations are ongoing. Meanwhile, in 2012, NASA signed a US\$17.8 million contract with Bigelow to



Blue Origin's orbital rocket New Glenn

Image: Blue Origin



Axiom Modules connected to ISS

Image: Axiom Space

develop the Bigelow Expandable Activity Module (BEAM), which was attached to the ISS in 2016, where it remains today.

Bigelow is currently developing the B330 standalone commercial space station for operation in low Earth orbit (LEO), cislunar space and beyond. A single B330 is comparable to one third of the current pressurized volume of the entire International Space Station. Bigelow Aerospace is developing two B330 commercial space station habitats that will be ready for launch any time after 2020. Indeed, at the end of 2017, Bigelow and United Launch Alliance (ULA) announced plans to launch a B330 module on ULA's Vulcan launch vehicle, placing it into low lunar orbit (LLO) by the end of 2022 to serve as a lunar depot.

The B330 will launch to LEO on a Vulcan 562 configuration rocket, the only commercial launch vehicle in development today with sufficient performance and a large enough payload fairing to carry the habitat. Once in orbit, Bigelow will outfit the habitat and demonstrate it is working properly. Once fully-operational, ULA's industry-unique distributed lift capability will be used to send the B330 to lunar orbit. Distributed lift will also utilize two more Vulcan ACES launches, each carrying 35 tons of cryogenic propellant to LEO. In LEO, all the cryogenic propellant will be transferred to one of the Advanced Cryogenic Evolved Stage (ACES). The now full ACES would then rendezvous with the B330 and perform multiple manoeuvres to deliver the B330 to its final position in LLO.

SpaceX sets sights on commercial spaceflight

Elon Musk has been very vocal in his plans for SpaceX to enter the commercial spaceflight sector by bringing humans to Mars. Development work towards this goal could be considered as starting in 2012 with the design of the Raptor rocket engine, which will propel all versions of the BFR launch vehicle.

Since one of SpaceX's key ethos is to make space travel affordable, the company's long-term plans envisage a re-usable launch vehicle capable of lifting 150 tonnes into space. The system will be powered by the Raptor bipropellant liquid rocket engines for both

stages, using densified liquid methane fuel and liquid oxygen oxidizer. The engine is expected to be test fired for the first time in 2020.

SpaceX aims to send its first cargo mission to Mars in 2022. The objectives for this first mission will be to confirm water resources and identify potential hazards in establishing initial power, mining, and life support infrastructure. A second mission carrying a crew is planned for 2024, with primary objectives of building a propellant depot preparing for future crew flights. The spacecraft used for transportation from Earth will also be utilized for the first Mars base.

Landing the first humans on Mars is one of the great races underway today. Recently, Boeing's CEO Dennis Muilenburg made the news when he claimed that the SLS rocket the company is developing for NASA would bring humans to Mars ahead of SpaceX. Boeing is currently developing the world's biggest rocket for NASA, complete with 9.2 million pounds of thrust, and measuring 38 stories tall. The first test firing is scheduled for 2019.

Indeed, when CNBC host Jim Cramer asked whether Boeing or SpaceX would get a man to Mars first, Muilenburg reportedly responded: "Eventually we're going to go to Mars, and I firmly believe the first person that sets foot on Mars will get there on a Boeing rocket."

SpaceX CEO Elon Musk responded concisely on Twitter: "Do it."

Blue Origin readies for suborbital space tourism

Not quite a household name yet (but surely it will be soon), Blue Origin is Amazon Founder Jeff Bezos' answer to developing technologies to enable private human access to space, dramatically lowering costs and increasing reliability.

The company has developed several launch vehicles with an ultimate focus on providing access to both suborbital and orbital space. The suborbital New Shepard spacecraft has performed several successful test and commercial satellite launches, including the launch of its pressurized Crew Capsule. Both launcher and capsule have been successfully re-landed after launch, making them suitable for reuse.

The Crew Capsule, which includes six large observation windows, is expected to be launched with crew on board in the near future, after which tickets for suborbital space tourism will be made available for sale. Passengers will experience weightlessness for about four minutes of the eight-minute flight, and be propelled to a height of 307,000ft after separation from the launch vehicle.

Blue Origin is also working on the development of the New Glenn vehicle, which has a reusable first stage. The orbital launch vehicle will be utilized for satellite launches but is also the company's answer to commercial spaceflight. The first test flights are expected to commence in 2020, although recent reports state this may be pushed back.

Axiom Space prepares for world's first commercial space station

American start-up company Axiom Space was established in 2015 with plans to develop and manufacture the world's first commercial space station. The company's vision is to make living and working in space commonplace as a means to sustained deep

space exploration and to improve the quality of life on earth.

"It is an honour to continue the work that NASA and its partners have begun, to bring awareness to the profound benefits of human space exploration and to involve more countries and private citizens in these endeavours," said Axiom Space CEO and President Michael Suffredini, who managed NASA's ISS program for a decade.

The company plans to link a module with the ISS in 2019; upon the retirement of the ISS in 2028, the Axiom module will be joined by additional elements that will function as the Axiom International Commercial Space Station. As such, Axiom will conduct astronaut training for commercial astronauts, host government and commercial partners, as well as space tourists.

For space tourists, an eight-day stay on the space station will cost US\$55 million, following 15 weeks of training prior to the flight. Passengers will have access to high speed WiFi, video screens, and a glass-walled cupola, reportedly the largest window observatory ever constructed for the space environment.

Orion Span plans Aurora Space Station

Orion Span is one of the latest space tourism start-up companies, having announced plans to build a private space station in LEO in March 2018. The Aurora Space Station will have a six-person capacity, two crew and four tourists, and will be designed, built and tested in Houston, Texas.

"We developed Aurora Station to provide a turnkey destination in space. Upon launch, Aurora Station goes into service immediately, bringing travellers into space quicker and at a lower price point than ever seen before, while still providing an unforgettable experience," said Frank Bunker, CEO and Founder of Orion Span. "Orion Span has additionally taken what was historically a 24-month training regimen to prepare travellers to visit a

space station and streamlined it to three months, at a fraction of the cost. Our goal is to make space accessible to all, by continuing to drive greater value at lower cost."

Space tourists will experience the zero-gravity environment, be able to float freely throughout the habitat, and take part in research experiments such as growing food while in orbit.

A virtual reality holodeck will be available, and customers will be able to stay in touch with loved ones on Earth via high-speed wireless Internet access. The Aurora Space Station will orbit the Earth every 90 minutes, allowing guests to view around 16 sunrises and sunsets every 24 hours.

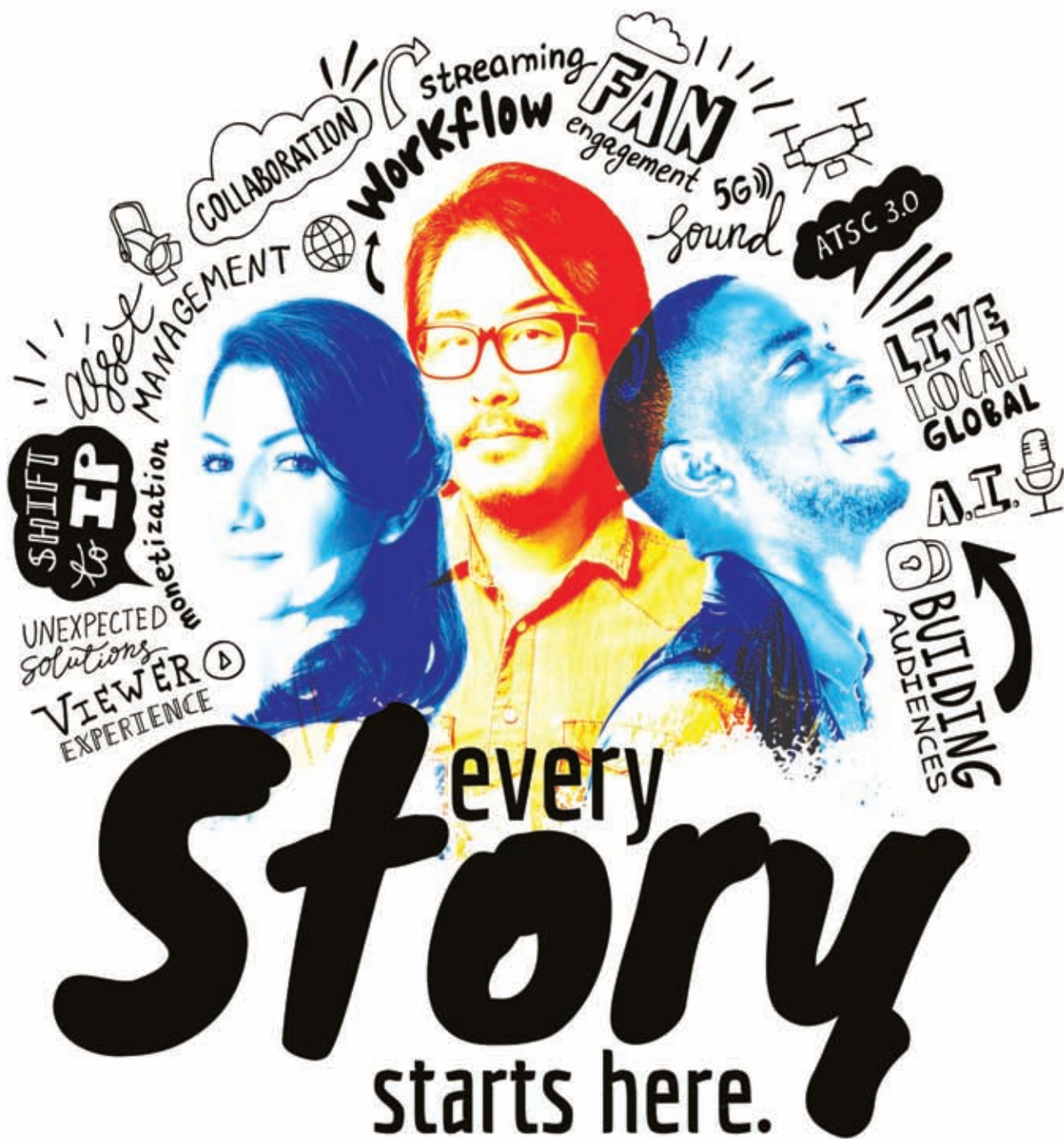
Orion Span has shortened the traditional 24-month astronaut certification down to three months, with the first phase being completed online. The next stage will be completed in person in Houston, and the final step will be finished onboard the space station.

Reports state that the Aurora Space Station will be launched in 2021 and will be accepting its first guests in 2022. A 12-day stay will reportedly cost US\$9.5 million, and a place can be secured with a US\$80,000 deposit. Within the first 72 hours of announcing the space station, four months of reservations were sold out.

Orion Span made an interesting announcement in June 2018, when it was revealed that the company is now accepting cryptocurrency payments for future reservations. Payments in Bitcoin, Ethereum, Bitcoin Cash and Litecoin will be accepted.

"To better reflect the global nature of Aurora Station, we're putting together these two worldwide resources - space and cryptocurrency - to further serve and improve access for our global clientele. This is part of our continuing mission: to make it easier than ever before to travel to and stay in space," said Bunker. "As a forward-thinking company, we're proud to once again be pioneering the leading edge of the space industry by streamlining the technology involved in getting there." ■





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Laser communications

LGS Innovations was established in 2006 to act as Alcatel-Lucent's sole sales and contracting channel for all classified and unclassified business with the US Federal Government. The company was acquired by Madison Dearborn Partners and CoVent in 2014, after which it continued to act as the exclusive reseller of Alcatel-Lucent products to the US Government. The company delivers a range of next-generation solutions that solve the most complex networking and communications challenges facing governments, critical infrastructure operators, and large commercial enterprises. Linda Braun, Sr. Technical Vice President of Photonics at LGS Innovations, talks about the company's latest activities with laser communications and other projects.

Question: In recent years, LGS Innovations has significantly expanded its areas of activity. Which markets are now key to the company's success, and how have they evolved over time?

Linda Braun: LGS Innovations continues to focus on developing advanced solutions in wireless communications, signals processing and analysis, optical networking, photonics, spectrum operations and management, routing and switching, and network assurance. Our focus is to give our commercial and government customers a technological advantage as they operate and execute missions in an increasingly crowded and complex communications environment.

One area that has expanded its activity is free space optical communications. LGS Innovations has publicly announced a number of recent wins with the National Aeronautics and Space Administration (NASA). We continue to expand our customer base and are currently working with NASA on three projects that will prove the viability of laser communications and open up the technology for more widespread adoption. We are building an optical modem for the Orion Capsule, an optical modem for the International Space Station, and the first deep space laser transmitter for the NASA Psyche mission.

LGS Innovations has also increased its market in custom lasers for sensing applications – we are a leader in high performance fibre-based lasers for communications and sensing applications. In an effort to arm our Department of Defense (DoD) customers with unparalleled detection and tactical mapping capabilities critical to situational awareness, we are focusing on building custom lasers for Intelligence, Surveillance and Reconnaissance (ISR).

Question: In October, LGS Innovations announced it was supporting NASA's Orion EM-2 Optical Communications (O2O) project by providing a modem



Linda Braun

Image: LGS Innovations

that will enable broadband data communications to and from the Orion Multi-Purpose Crew Vehicle, which is designed to take humans to lunar orbit. What can you tell us about the deal and the technology you'll be enabling?

Linda Braun: LGS Innovations will support the NASA Optical-to-Orion (O2O) project. For this pathfinder program, LGS Innovations will develop an optical modem for a free space optical communication system that will fly aboard the Orion mission. It will be the first demonstration of optical communication to and from a human spaceflight mission in lunar orbit. The O2O modem will leverage LGS Innovations' rich heritage in free space laser communications and fibre laser technology.

The O2O program will use lasers to encode and transmit data at rates ten to 100 times faster than today's communications equipment, requiring significantly less mass and power than equivalent radio frequency (RF) communications systems. The modem will transmit data from the Orion capsule in lunar orbit directly to ground. This new capability will greatly increase the amount of scientific data transferred from Orion, while supporting ultra-high-definition video to and from space.

Question: Laser technology is expected to revolutionize communications capabilities for passengers and crew on missions beyond low Earth orbit (LEO) in the years to come. What benefits will laser communications bring to these missions, in terms of both crew welfare and scientific advancement?

Linda Braun: Advanced laser communications technology facilitates a dramatic increase in

communication capacity. This leap in performance is accomplished while attaining significant reductions in size, weight, and power, in contrast to the prior generation terminal's RF-based approach.

The ability to share - on-demand - massive amounts of data with very low latency has the potential to enable new forms of highly interactive, adaptive and widely distributed real-time sensing experimentation. In terms of throughput and latency, this dramatically expands the capacity to support remote sensing payloads for LEO applications and beyond.

By increasing communications efficiency, LGS Innovations will help facilitate a faster exchange of data to the scientific community. LGS is proud to support NASA's mission and drive the evolution of photonics technology.

A step-function in the ability to monitor health based on additional communications capacity is an advantage when it comes to crew welfare. Given low latency, in addition to providing the expanded bandwidth needed to support ever increasing imaging modalities and augmented reality content, performance of emergency surgical procedures may become a viable option.

Similarly, an isolated crew may enjoy the advantages of immediate, on-demand, virtual connectivity for sharing and accessing information for social, entertainment, and educational purposes far beyond current capabilities.

Question: Laser communications technology is expected to have far-reaching implications, proving particularly useful in other sectors, including government and military applications. What can you

tell us about the potential in this area and others?

Linda Braun: Today's military missions require reliable access to mission-critical data in near-real time, regardless how remote the location or big of a file. MILSATCOM networks have to operate on smaller, lighter and cheaper platforms that are secure and difficult to jam. Those systems need to be capable of carrying more and more traffic in an increasingly congested radio frequency environment.

Traditional radio frequency infrastructure struggles to meet these demands. Laser communications links operate with significantly lower transmit powers and apertures but at much higher data rates than radio frequency links.

Additionally, the bandwidth available for transmission is much greater. A Ka-band link might have 1GHz of bandwidth allocated, but the bandwidth available for laser communications, largely determined by the bandwidth where good amplifiers can be made, is almost 8000GHz. The need for bandwidth-efficient modulation is greatly reduced, leading to lower requirements for signal-to-noise. Furthermore, free space laser communications technology leverages the very large technology base of commercial optical fibre communication systems, where, for example, coherent modems handling 100 Gigabits/s/carrier are readily available for about \$25K.

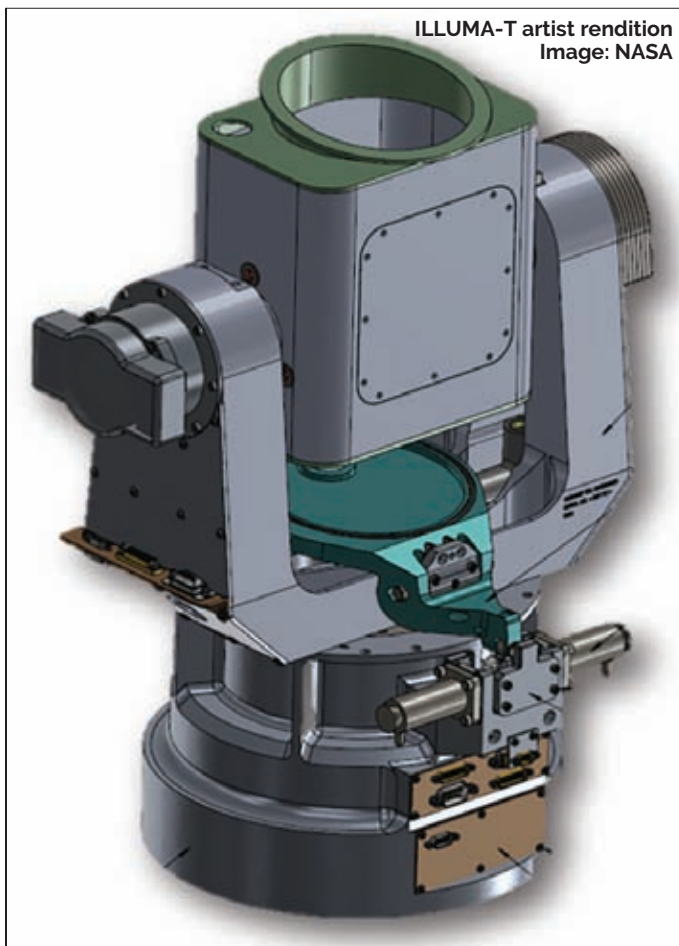
To deliver high-bandwidth communications capabilities to the warfighter, while keeping costs in check and providing higher security and anti-jam protection, it's clear that laser communications will become a part of future MILSATCOM networks.

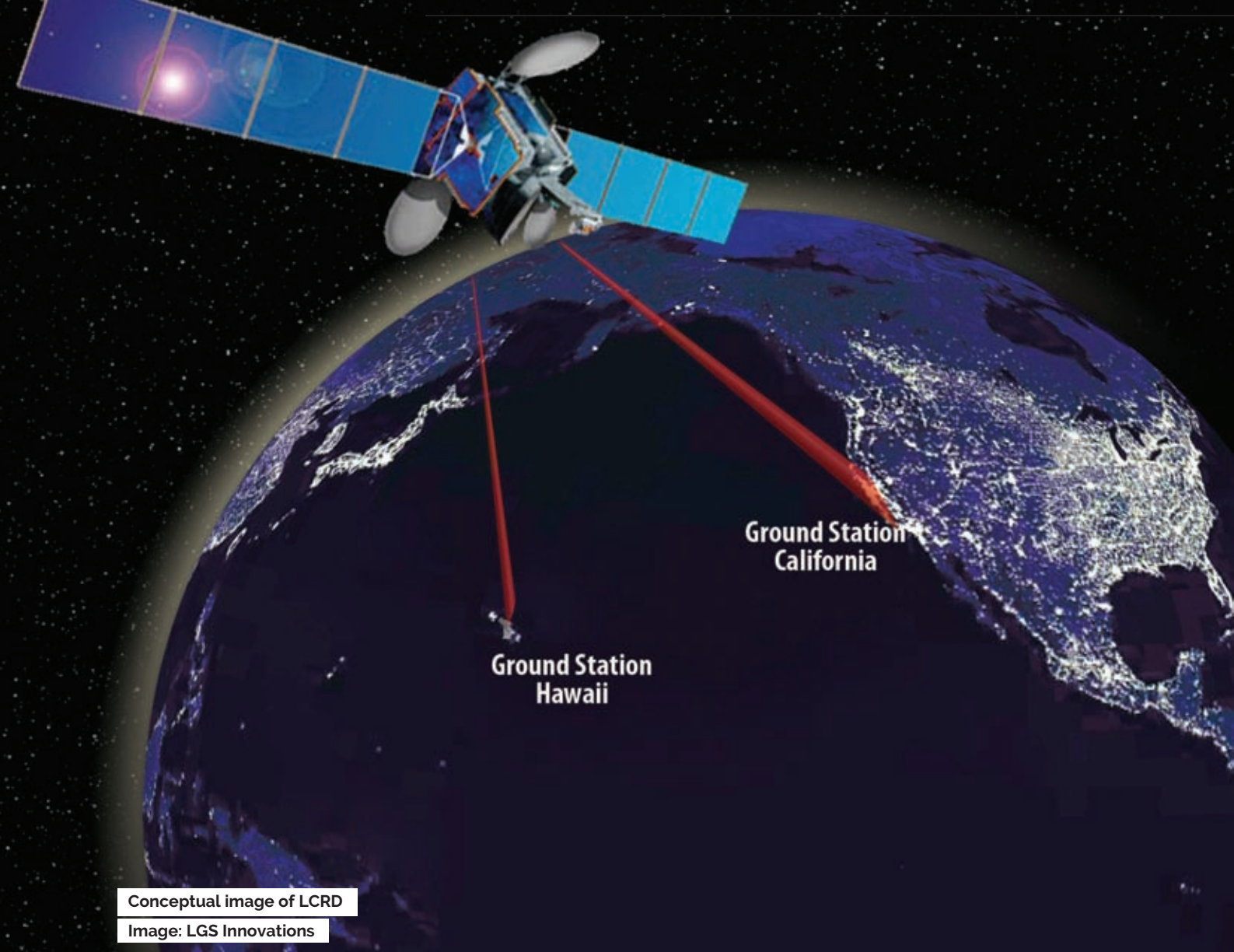
Question: Cybersecurity is a major concern amongst government, military and commercial sectors alike right now. How is LGS Innovations addressing these concerns, and what are the different priorities for each of these markets?

Linda Braun: LGS Innovations prioritizes enhanced security for all types of networks and communications, both government and commercial. We develop capabilities for security assessments of complex, large-scale networks, assessing their vulnerabilities and associated mitigation approaches.

We continue to expand our research and development to ensure alignment with our customers' critical cybersecurity and cyber mission needs, building on our experience in network assurance, secure network integration, cyber support services telecommunications studies, and advanced cyber research capabilities. Key focus areas include network reconnaissance, supporting effective pen-test and analysis of the cybersecurity of customer networks.

Improved security is an additional critical advantage of laser communications over radio frequency links. Photonic technology uses a narrow laser beam. An eavesdropper can't detect a signal unless he's inside the beam. Similarly, a jammer can't effectively jam a receiver unless he's inside the field-of-view of the receiver. Both the transmitted beam spot size and the receiver field-of-view are reduced over radio frequency systems by the roughly 6400x ratio of the carrier frequencies. For example, even if a radio frequency aperture can be 10 times larger in diameter than an optical aperture, the footprint of the optical beam on Earth is 600 times smaller.





Conceptual image of LCRD

Image: LGS Innovations

Question: We're hearing a lot about spectrum management these days; how are the needs and challenges of different users evolving, and what's the answer to the 'spectrum crunch?'

Linda Braun: With the proliferation of connected devices and 5G deployment around the corner, the already growing demand for frequency to transmit data will increase dramatically. Spectrum will become more crowded and managing this precious resource will become more complex, raising the risk of interference. For military customers, compliance with US spectrum allocations is only a small part of the problem. Military radars, communications, sensors, and weapon systems must manoeuvre within and around spectrum, which is allocated differently around the world.

There are no easy answers to the 'spectrum crunch'. We are focused on helping government agencies as well as critical infrastructure operators and telecom services providers manage this finite resource. We are implementing innovative solutions to monitor spectrum use in real time and identify violations. For example, LGS Innovations is currently supporting the National Oceanic and Atmospheric Administration (NOAA) with a radio frequency interference monitoring system to mitigate the risk of potential interference by commercial wireless carriers sharing the spectrum with NOAA satellite operations.

With the shortage of the radio frequency spectrum,

laser communications technology offers another advantage as optical spectrum is unlicensed and available at no charge.

Additionally, with the narrow beam, the problem of different users interfering with each other is greatly reduced.

Question: What's on the horizon for LGS Innovations in the rest of 2019? Which projects can we expect to hear more about?

Linda Braun: We will continue researching and investing in the technologies mentioned previously to develop solutions for today's communications issues, while anticipating those that have not yet surfaced. We are expecting to be involved in new contracts and develop more solutions in the Intelligent Spectrum Management, free space optical communications and cybersecurity markets.

We conducted hiring events across country this year and already added a few hundred highly talented people to the team. We are looking for more scientists and engineers who want to push the innovation envelope.

From propelling scientific exploration of space or enabling live video transmission the next time humans go into lunar orbit to making a life-transforming impact on people's lives, this is the kind of progress we want to enable with advanced communications technology. ■



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Breaching the bottleneck

UK-based Orbex was founded in 2015 to develop one of the world's most advanced, low-carbon, high-performance micro-launch vehicles, in order to provide access to polar and sun-synchronous low Earth orbits (LEO) from Europe. Having already received funding from two of Europe's largest venture capital funds (Sunstone Technology Ventures and the High-Tech Gründerfonds), as well as the UK Space Agency, the European Space Agency (ESA) and the European Commission Horizon 2020 programme, Orbex is well on its way to changing the face of the launch sector. Chris Larmour, CEO at Orbex, answers questions on the latest developments in the NewSpace sector, and Orbex's place within the rapidly-changing marketplace.



Chris Larmour

Image: Orbex

Question: Orbex is a pretty new company in space sector terms; can you give us an overview of the company's foundation development, and raison d'être?

Chris Larmour: Orbex is a private European spaceflight company headquartered in the UK, with subsidiaries and production facilities in the UK, Denmark and Germany. We founded the company in 2015 with the objective of developing orbital launch vehicles to launch small satellites into low Earth orbit (LEO). We are one of the few private spaceflight companies to have staff with credible, practical experience in the development of micro-launch vehicles and rocket engines.

We have people with very strong spaceflight backgrounds, including NASA, ESA, Ariane 5 and Ariane 6, as well as a group who have built five suborbital rockets. We also are fortunate to have the former Director General of the European Space Agency on our Advisory Board, plus a wealth of other experience and skills within the business.

Prior to 2018, we deliberately kept quiet about our work so that we could focus on delivering tangible progress, only sharing our development with a select group of people. In the Summer of 2018, we announced at Farnborough that we had been selected by the UK Space Agency to launch orbital vehicles from the newly-announced UK Vertical Launch spaceport in Sutherland in the Scottish Highlands, as part of the main consortium. And alongside that, we announced the results of our first major funding round.

Since Farnborough, we have been surprised by the enormous interest that has been sparked. We are in a unique position because we will have a European launcher launching into orbit from a site in continental Europe, and that's a first.

Question: Let's talk about your launch vehicle plans. What's the overall vision, and what can you tell us

about the design and technology, and progress to date?

Chris Larmour: We are working towards a launch in 2021, however this industry is notorious for getting the timings wrong, so we treat that date with caution. The 2021 timeframe is for the launch in Sutherland, but we are also working with other launch sites in Europe.

With our orbital launch vehicle, Prime, we went back to the drawing board to address a key problem with micro launchers. Micro launchers have always suffered from a fundamental mass challenge. There's a square-cube law that applies to rockets, which says that the bigger you get, the more efficient they become volumetrically, because, very simply, you get more volume enclosed by the metal or carbon fibre on the outside. Conversely, the smaller the vehicle, the heavier and less efficient the vehicle becomes comparatively.

We thought about how to solve this problem by re-architecting the vehicle and decided to use propane as the fuel. Propane has some unique properties that allow us to build a vehicle that is about 30 percent lower mass than anyone else in this category, which makes Orbex less costly while offering higher performance. We're also able to use bio-propane, which is chemically equivalent, but is also a clean, renewable fuel that helps makes our Prime launchers up to 30 percent lighter and 20 percent more efficient than any other vehicle in the small launcher category, packing more power per cubic litre than many heavy launchers. It also cuts carbon emissions by 90 percent compared to old-fashioned hydrocarbon fuels.

Another problem we tried to solve is that people are rightly worried about the orbital debris or space junk. We certainly didn't want our launcher to be dropping litter in space. So, we deliberately set out to architect the vehicle so it would not leave any debris on orbit. We deliberately designed features into the Stage 2 to de-orbit very rapidly, so it burns up on re-entry. We created

a new zero-shock staging system, which leaves zero orbital debris. It also features a novel reusability concept, with a new low mass recovery and re-flight system, which is now patent-pending.

From the outside, it may look like a normal rocket, but on the inside, there is a lot of innovation in areas that are subtle but add a lot of value in the ability for the rocket to lift at the right performance level.

Question: The UK is a booming region as far as the space sector goes, with great plans for the NewSpace era of the future. What's your assessment of the potential, and Orbex's place within it?

Chris Larmour: The space sector in the UK is a hidden jewel, it's worth £14-16 billion today. The UK is very strong in other parts of the value chain, but does not have a launch capability. This is the gap in the supply chain that our solution will close. Our vision is to help create an end-to-end solution where the UK builds satellites, builds rockets and launches them from the UK, creating a complete joined-up value chain. This will become a virtuous circle, a complete ecosystem which will bring technology and business benefits not just to the UK, but to the whole European satellite industry. We see Orbex as being a central, enabling player in making this happen.

Question: In July 2018, Orbex secured UK£30 million in public and private funding for the development of orbital space launch systems. What can you tell us about this achievement, and how will the funds help Orbex move forward?

Chris Larmour: Yes, we secured £30 million (\$40 million) as a mix of public and private funding for the continued development of our orbital launch systems. This came from two of Europe's largest venture capital funds

(Sunstone Technology Ventures and High-Tech Gründerfonds) as well as private investors, the UK Space Agency, the European Space Agency and the European Commission Horizon 2020 programme, as well as a strategic investment from Elecnor Deimos. The fact that we were able to attract this degree of support from experienced partners across the industry is a validation of the uniqueness of the vision, the sophistication of the rocket design and the potential for the business. Externally, being a well-funded company in this sector has benefits too, as people recognise that you're a serious player.

Question: In the same month, Elecnor Deimos acquired a stake in Orbex and made the company its preferred supplier of all launch services required to place Elecnor Deimos satellites into orbit. Can you give us a little more detail of the deal, and Elecnor Deimos' plans for the satellite sector?

Chris Larmour: Under the terms of the agreement, Orbex will become the preferred supplier of all launch services required to place Elecnor Deimos satellites into orbit. So far, we are planning 20 launches for the company, which is a very significant volume for a micro launcher.

The other side of the deal is that Elecnor Deimos became the preferred supplier of various critical launch systems required to develop and operate the Orbex launcher system, including the Guidance, Navigation and Control (GNC) system.

The partnership with Elecnor Deimos is significant for us on a number of levels as it demonstrates that as well as technological maturity, we have achieved a milestone in business maturity to become the preferred launch partner for an organisation as significant as Elecnor



Launch site - Scotland

Image: Orbex

Deimos. It also helps us maintain our accelerated pace of development, as we are able to incorporate tried-and-tested critical launch systems from Elecnor Deimos ranging from navigation to ground and mission control systems.

I can't speak on behalf of Elecnor Deimos but their CEO, Miguel Belló Mora was publicly quoted as saying: "The huge potential of Orbex quickly became clear to Elecnor Deimos, which is why we became both an investor in the company as well as a strategic partner. By using a number of our advanced navigation and mission support systems, Orbex is leaping ahead in its ability to safely and efficiently execute small satellite launches in the near future. This in turn helps Elecnor Deimos as it gives us access to innovative and efficient launch vehicles, which will be launching from several sites within Europe."

Question: We hear that Orbex is also building a launch vehicle factory and Spaceflight Mission Control facility in Scotland. Can you provide an outline of your plans?

Chris Larmour: We have already purchased a second production facility close to the launch site, the first one being our existing 2000m² factory. The second site will become our main production and integration facility for final assembly. We needed a site which addressed two key elements.

Firstly, it needed to be relatively close to the launch site in Sutherland. Secondly, it needed to have reliable infrastructure fundamentals like good road access as well as proximity to airports and engineering talent.

We think we've got the right balance with the site we've acquired, and we'll be unveiling more about that

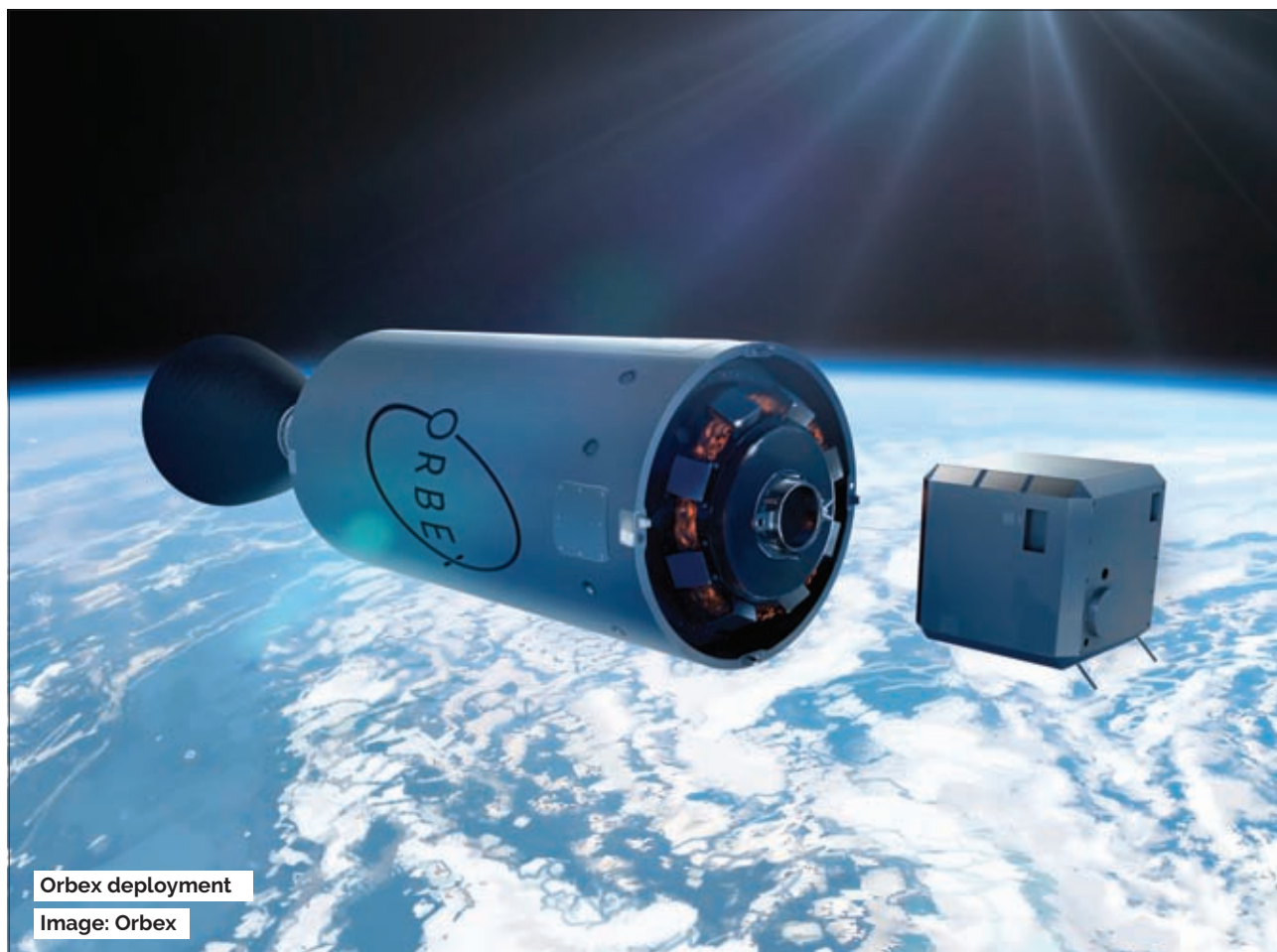
new facility quite soon.

Question: What are your expectations for the rest of 2019 and beyond?

Chris Larmour: The big picture is that the smallsat launch market is projected to grow strongly to around US\$60 billion between 2018-2030, with a strong shift towards more international satellite operators. Each satellite has a life expectancy of 3-5 years, creating a strong ongoing demand for upgrade and replenishment, and an ongoing need for our services.

For Orbex, 2019 is going to be another interesting year. There is a lot on the horizon, most of which I can't divulge at the moment. But you can expect to see more evidence of technology innovation and maturity, as well as major news regarding our progress as a business. From here, step by step, we will be doing everything we can to become the natural choice for companies looking to launch small satellites in Europe.

There is a quiet revolution taking place, thanks to small satellites. Smallsats are now able to perform a huge range of tasks at very low cost, making them a smart choice for satellite operators both commercially and logistically, and you can see that many satellite firms are looking closely at this new opportunity. But there is currently a huge bottleneck in getting smallsats delivered into orbit, which means that satellite operators face quite severe financial challenges. With Orbex, international smallsat operators will have access to a new class of launch service which was designed exclusively to serve their needs. We intend to relieve that smallsat bottleneck so that satellite operators have a reliable, long-term solution for orbital access. ■



Orbex deployment

Image: Orbex



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COMING SOON...

Enjoyed this issue of NewSpace International magazine? Hold onto your hats, because there's much more to come!

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- News
- **Interview:** Exotrail
- **Interview:** Earth-i
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- **Feature:** Manufacturing in Space
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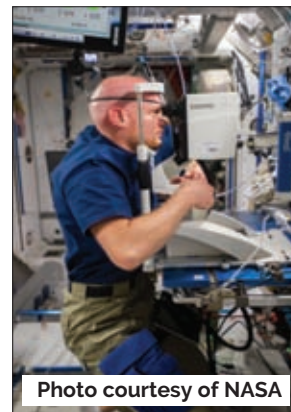


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We thank all our partners, clients and suppliers for helping us significantly grow our business and we remain committed to the same degree of excellence, spirit of innovation and customer delight. Above all, we commit to reward our customers with unsurpassed technologies and solutions developed by our talented and loyal team that has earned your trust over the past 30 years

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