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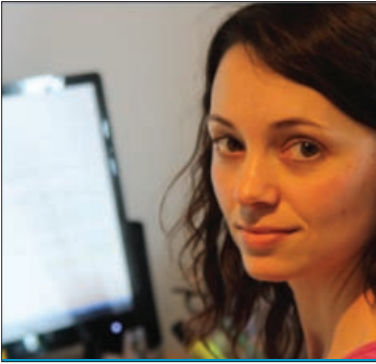
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**Dr Amy Saunders****Editor**

A pet topic of mine, we've been hearing a lot about satellite-supported quantum communications over the last few years. The proof-of-concept QUESS mission proved beyond doubt that satellites in orbit can utilise the principle of quantum entanglement to enable hack-proof, 100 percent secure communications at long distances. Experiments to test the boundaries of this technology are ongoing.

September, however, has brought with it some game-changing news. Crypta Labs has completed its SPRINT (SPace Research and Innovation Network for Technology)-funded project, in collaboration with the University of Southampton, in developing a Quantum Random Number Generator (QRNG) for space that will facilitate quantum secure encryption of satellite data. Concluded for use in low Earth orbit (LEO), the QRNG devices were tested in a thermal vacuum, cycling between temperatures of -50°C and +80°C, during which the team were able to generate high quality random numbers at a bitrate of 40Mbps. The devices were then subjected to vibration tests simulating the launch environment of a Soyuz and Falcon 9 vehicles. All devices successfully completed the tests and came out fully operational.

In due course, the team hopes that this will encourage dialogues with defence and aerospace vendors looking to integrate quality quantum random numbers to provide the next constellations of quantum satellite communications.

Meanwhile, in this issue of NewSpace International, we speak with Spaceport Cornwall's Melissa Thorpe on the development of the site as part of a holistic space nation; and also, with Dennis Silin from Exodus Orbitals about the company's new satellite-as-a-service solution and participation in Australia's Moonshot accelerator programme. Jeroen Cappaert from Spire Global Inc. opines on leveraging the potential of AI and edge computing in space to solve real world challenges. Meanwhile, we've explored the very near future of off-world connectivity, wherein several game changing projects are expected to be completed in the next couple of years; lunar business models and present-day capabilities with input from Frontier Electronic Systems' Chuck Gray; and finally, the future of rocket propulsion with insight from Matt Villarreal of Infinite Composites.

A quantum game changer





Front cover: Photo courtesy of Shutterstock

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There can be no spaceflight without propulsion. Its limitations are often the reason behind what we cannot yet achieve in space. With journeys to the Moon, Mars, and deep space an evergreen topic, and satellites increasingly being fitted with their own manoeuvring systems, fuel systems are getting more efficient, more innovative, and friendlier to the planet to match demand. Propulsion is a key to the space economy and the work of interstellar exploration.

Leveraging the potential of AI and edge computing in space 16

AI and edge computing on the edge of space could help organizations track everything from illegal shipping activity to climate change. The technology is ready and waiting on the construction of the frameworks in order to bring this innovative new step to reality.

Offering an edge in the race to space 18

With constellation services continuing to flesh themselves out, the most competitive business cases remain up in the air. As providers struggle to provide the best service at the lowest cost, Dennis Silin, CEO at Exodus Orbitals, introduces a new satellite-as-a-service solution, proven by the Moonshot accelerator program, which could offer an edge.

Connecting to the Moon and beyond 20

As mankind edges ever closer towards an intergalactic future, with space tourism already being brought to reality earlier this year, assured, reliable connectivity off-world is a vital component of our future. With secure world-to-world communications, travellers between planets can better achieve their goals.

The progress of NASA's Artemis missions and the commercialization of the moon 24

Our lunar missions have a history of being understood as sensational achievements overshadowing all other achievements beyond our planet. With many long-awaited Moon missions entering execution in the 2020s, including a manned journey, expectations are high. Recent NASA strategies to incorporate commercial operators could be a sign of a new culture in the world of space exploration, though it hasn't come without challenges.





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Sateliot enters the USA via EvoNexus

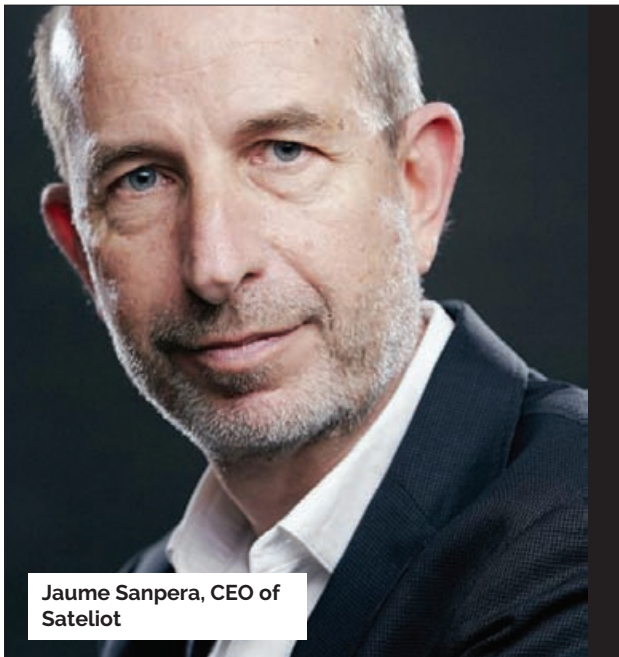
Sateliot, the satellite operator that will launch a constellation of nanosatellites to universalize the Internet of things with 5G coverage, will enter the US market before the end of this year thanks to EvoNexus – the accelerator sponsored by the microchip manufacturer Qualcomm and the operator Verizon.

After evaluating more than 414 companies from around the world, EvoNexus has recognized the technological and innovative potential in the fields of space and telecommunications of Sateliot and six other companies, which have been selected to develop 5G use cases together with strategic partners in their areas of expertise.

Thus, the support of this accelerator will allow Sateliot to grow in the United States from its headquarters in San Diego, in addition to working directly with experts in telecommunications and IoT devices from Qualcomm and Verizon, the world's leading operator by turnover.

This mentoring, training and networking program will also boost the new round of financing that Sateliot is already preparing with an eye on American funds interested in its constellation of nanosatellites that will universalize the IoT with 5G coverage.

However, EvoNexus is not the only accelerator that has bet on Sateliot in recent months. The company has also participated in Seraphim's Space Camp, the first fund in the space sector. This is a launching pad based in the United Kingdom, which in its last edition brought together seven start-ups in the space sector to boost their business and attract investment.



**Jaume Sanpera, CEO of
Sateliot**

To include your news in NewSpace International magazine please contact
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The company is also part of the Singapore Space & Technology (SSTL) startup accelerator program, which gives Sateliot visibility with investors and serves as a springboard for the development of its business in the Asian telecommunications industry.

According to Jaume Sanpera, CEO of Sateliot, "our entry into this type of project opens up new avenues for growth, financing and technological capacity, while at the same time connecting us with strategic stakeholders around the world that will be key to the evolution of our technology and our business plan."

Sateliot is the first satellite telecommunications operator that will provide global and continuous connectivity to all the elements that will make up the Internet of things (IoT) universe – such as the connected car or the connected home – under the 5G protocol.

Thanks to a constellation of state-of-the-art nanosatellites, located at low altitude and acting as mobile towers from space, Sateliot is the perfect complement to large telecommunications companies by providing them with the necessary infrastructure to extend their coverage where terrestrial technologies do not reach.

SSTL secures ESA InCubed funding

Surrey Satellite Technology Ltd (SSTL) has secured European Space Agency InCubed programme financial and technical support to demonstrate a high throughput, flexible and intelligent payload downlink chain for small Earth observation satellites.

Currently advanced and innovative satellite imaging payloads are producing data with ever increasing dimensionality, volume and rates which can exceed small satellite's downlink bandwidth. To tackle the onboard data bottleneck SSTL is leading a consortium that includes the University of Surrey and Craft Prospect Limited to develop and demonstrate new capabilities for SSTL's Flexible & Intelligent Payload Chain (FIPC) solution. The FIPC's advanced hardware architecture enables a new intelligent and adaptive data downlink and a state-of-the-art framework for software defined onboard data processing to realise a payload chain capable of handling the throughput rates of future small Earth observation satellites. The framework enables processing applications which include data calibration and image compression to machine learning (ML) for image classification and information extraction towards greater satellite autonomy.

Phil Brownnett, SSTL's Managing Director said "The FIPC solution will significantly improve the capabilities of small earth observation satellites by increasing data rates to match the capacity of the onboard imager system. This will boost both the volume and the complexity of the data that can be downlinked on a single satellite pass – a step-up in capability that will match our customer's business plans and ambitions."

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Telesat selects Ciena for low Earth orbit terrestrial network technology

Telesat, one of the world's largest and most innovative satellite operators, is deploying routing and switching platforms from Ciena for its Telesat Lightspeed terrestrial backhaul network. Ciena's advanced routing and switching technology will ensure that Telesat has a modern, cost-effective network that takes advantage of emerging technologies including network functions virtualization (NFV) and edge computing to efficiently support both existing and future customer requirements.

The Telesat Lightspeed network will initially be comprised of 298 advanced low Earth orbit (LEO) satellites that seamlessly integrate with terrestrial networks. LEO satellites operate 25 to 30 times closer to the Earth's surface than traditional satellites and can process data with ultra-low latency—typically on par with fiber-optic speeds, even to the world's most rural and remote locations.

Ciena is supplying hardware and software that will provide high-speed, high-capacity connections to governments, telcos, mobile operators, and other enterprise customers for the delivery of 5G, cloud computing, video, and other bandwidth-intensive broadband services.

Telesat will use Ciena's 3926 and 5170 platforms to provide agile, assured MEF-compliant services at its points of presence (PoPs), as well as terrestrial connectivity to as many as 50 Earth-based landing stations. The Ciena platforms have advanced quality of service (QoS) mechanisms, including hierarchical ingress metering, that will provide Telesat with fine-grained control of network traffic. Ciena's Manage, Control and Plan (MCP) domain controller will provide highly effective software control and automation to drive business agility. Additionally, Telesat is utilizing Ciena Services for terrestrial network design, implementation, and testing.

"As the leading provider of aggregated, global Tier one carrier connectivity, Ciena's field-proven routing and switching technology will ensure flexible, reliable connectivity between our Earth station antennas and Points of Presence throughout the world. The seamless integration of on-ground data networks with our advanced Telesat Lightspeed satellites will ensure unmatched speed and performance for our global enterprise and government customers," said Aneesh Dalvi, Director, Landing Stations and User Terminals, Telesat.

"Telesat's enterprise customers—MNOs, ISPs, aviation, and maritime companies—are seeking high-throughput, super-low-latency connectivity to support delay-sensitive applications like cloud-based services. Telesat Lightspeed, powered by Ciena networking technology on the ground, makes reliable satellite broadband at fiber-like speeds possible," said Bruce Hembree, Vice President and General Manager, Americas, Ciena ■

Skyrora agrees first multi-launch deal with Shetland spaceport for the next decade

British rocket company Skyrora has agreed a multi-launch deal with the SaxaVord spaceport on Unst, the most northerly of the Shetland Islands, as it moves closer to launching its XL rocket in 2022. This is the first agreement Skyrora has made with a Scottish Spaceport. If successful, this could be the first rocket to go to space from the UK. The multi-launch agreement with SaxaVord will run for the next decade, giving Skyrora the ability to build towards its target of 16 launches a year by 2030.

According to a study by Scottish Enterprise last year, forecast income from Scotland's space sector could reach over £2 billion by 2030 with plans to double income to £4 billion while providing data solutions to combat climate change. This launch agreement will build on the impressive development of the Scottish space sector in recent years, creating even more jobs in an industry that has already grown 12 percent year-on-year while the UK as a whole has grown 3 percent.

Beyond this, the move brings the supply chain of the sector all within Scotland, providing huge environmental benefits by addressing the sustainability and administrative issues around exporting to different launch sites across Europe.

Once operational, the SaxaVord spaceport is expected to create 140 jobs locally, with an additional 70 jobs across the Shetland. Shetland Space Centre recently changed its name to SaxaVord Spaceport, rebranding to position itself at the heart of the new space economy in Europe.

Skyrora has been testing increasingly larger rockets with short high-altitude launches since 2018 in the build up to the proposed launch next year. Last year, it conducted the first rocket test on UK soil in 50 years as well as launched its Skylark Micro from Iceland. These preparations have been gradually moving towards ultimately launching the three-stage Skyrora XL rocket to orbit, standing over 22 metres tall and capable of carrying up to 315 kilograms to orbit. Skyrora's aim is to create over 170 jobs by 2030. In just the last few months, their company team has expanded by 30 percent. ■



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Pillar of Britain's space economy

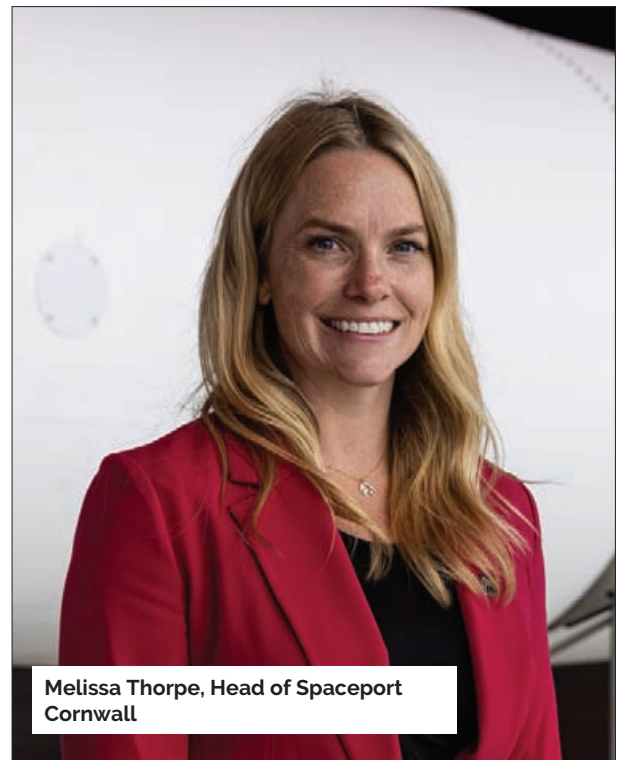
With plans to facilitate some of the UK's first space launches in 2022, Spaceport Cornwall has been hard at work as a pillar of Britain's space economy to see government and business expectations met, as well as lay the foundations for further growth as a holistic space nation. Melissa Thorpe, Head of Spaceport Cornwall, outlines some of their recent work, and what they hope to achieve in the coming years.

Laurence Russell, Assistant Editor, NewSpace International

Question: Spaceport Cornwall is holding a set of exhibits showcasing space technology old and new, supported by G7 Legacy funding. Part of the program involves the future of space in Cornwall. What will we learn there?

Melissa Thorpe: The three exhibits will take visitors on different journeys of the space industry in Cornwall.

The first is our 'Story of a Satellite' which tells the journey of a UK satellite from design to build to launch and how the data is used. With Goonhilly on our doorstep, we have innovative work going on with satellite communications and the viewer will learn how they are benefitting life on Earth and more particularly, how we aim to use satellite data to help both the environment and Cornwall's communities.



Melissa Thorpe, Head of Spaceport Cornwall

Our exhibit at Eden Project will highlight environmental intelligence and space and how we are launching the technologies that will benefit our planet.

The final exhibit at Royal Cornwall Museum will take a look back at the pioneering history of Cornwall and how launch is just the next chapter in the story for the county.

Our main objective is to inspire the STEM professionals of the future, so these exhibits will showcase the courses and apprenticeships due to start



Virgin Orbit LauncherOne. Photo courtesy of Virgin Orbit

at Truro & Penwith College and the jobs that will be created within Cornwall thanks to launch.

Question: One of the exhibitions will be displaying a replica of Virgin Orbit's LauncherOne rocket, which will launch from Spaceport Cornwall in 2022 - could you outline those plans?

Melissa Thorpe: Yes, we are Virgin Orbit's key delivery partner in Europe, and Cornwall Airport Newquay will be the site of the UK's first ever horizontal launch in 2022. It's also one of the only places in the world to fully integrate space launch into an active civilian airport. So, it will be a truly historic moment and a huge boost for the space sector and the wider community in Cornwall. This launch will also deliver Kernow Sat 1, a community satellite, into orbit as part of the payload.

Once fully operational, launches by Virgin Orbit will be low frequency but high quality and high value. We will be looking at two to three launches per year in the first few years and will progress to a maximum of eight.

Question: You'll also be exhibiting information about Kernow Sat 1, the UK's first community satellite. Could you tell us about it?

Melissa Thorpe: Kernow Sat 1 is tasked with an ocean health mission that will bring the value of space close to home by engaging audiences across Cornwall. This includes local businesses, charities, and schools. The satellite has received government funding and is the first to be designed, manufactured, and launched in Cornwall. The intention is for it to form part of the payload being sent into orbit next year on LauncherOne.

The build is to be undertaken in collaboration with the University of Exeter and KISPE Space. They will share expertise and knowledge with Spaceport Cornwall's Outreach Team, who in turn will work alongside Truro and Penwith College, using their new Space Technology Training programme to build Kernow Sat 1 in Cornwall. Kernow Sat will be launched by Goonhilly Earth Station and the data will be brought back to Cornwall and processed through local schools.

It's an innovative community approach to space that will set a precedent for future missions. Fostering collaboration across industry and bringing space closer to local communities, and part of Spaceport Cornwall's mission of democratising space and championing the use of satellites for environmental monitoring. Bringing the community together to solve issues around marine health and the blue economy in Cornwall.

Question: Your goal is to inspire the next generation of STEM experts by illustrating what we can achieve for our planet in space and helping prospective students see themselves in such careers. What's the most important thing you'd like to show children curious about space?

Melissa Thorpe: Emphasising STEM as a career option in Cornwall is very important to our team. We do a lot of work with schools in Cornwall, with the ambition of engaging with every single school by 2022. We're hoping that the exhibits and seeing launch happening on their doorstep next year will be a huge motivator for them.

However, we also need to show them the pathways into the industry and ensure that local colleges and universities are part of the journey. Being part of the space industry is no longer about just being an astronaut

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or astrophysicist anymore, and we want to showcase all the amazing jobs in the sector across all interests.

There's going to be plenty of opportunities for a career in the space sector in the coming years, and any child that has ambitions to work in STEM will be well-equipped to do so. We're looking to create 150 exciting new jobs within the aerospace and space sector in Cornwall and tonnes more in the supply chain and we want them to know that's happening.

Question: What role can the UK space economy play on the world stage? Though we aren't the largest space power, is there anything we can be the best at?

Melissa Thorpe: The UK is a powerhouse for satellite building/ manufacturing - which may come as a surprise to some people. We build a large proportion of the world's small satellites yet have no launch capability. It is estimated that over 13,000 satellites are required to be launched by 2030. Compared to the 3,300 currently active satellites, this represents a massive growth in the demand for affordable access to space.

A target has been set by the Government for Britain to have 10 percent of the global space industry by 2030 and with increased launch capability this is achievable. If we can launch the satellites here that we are currently sending overseas once manufactured, we can really grow the whole launch market and the manufacturing market all around the UK.

Question: Given the environmental tone of the G7 summit, Spaceport Cornwall's collaboration with space debris groups like Astroscale and D-Orbit, and the government's advocacy of action against space debris, does the spaceport have its own stance on the subject of space sustainability?

Melissa Thorpe: As a gateway to space, our Spaceport

has sustainability and responsible launch at the heart of our activities. We know the value of space technologies, especially satellites, in helping us fight climate change, however we need to get those technologies into space in a more transparent, and cleaner way.

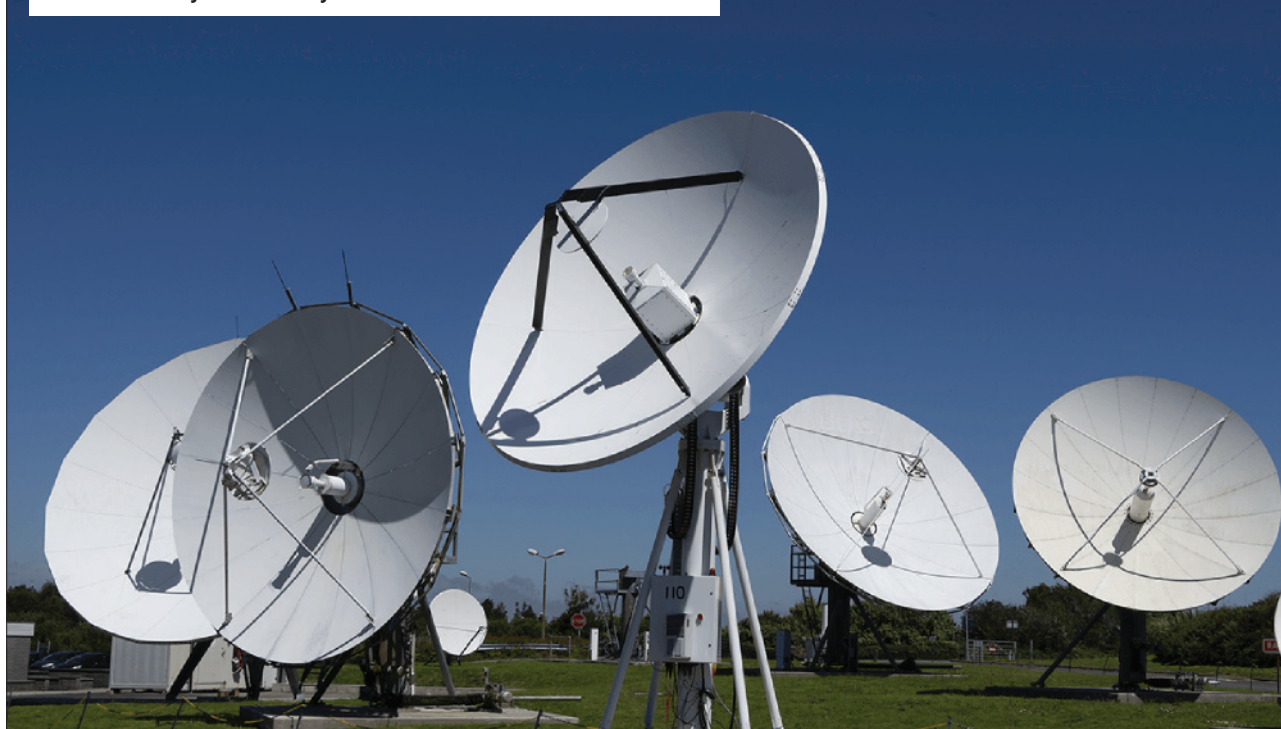
We've been doing a lot of work to make Spaceport Cornwall as sustainable as possible and are releasing our Sustainability Plan this autumn. Our plan will include our transparent carbon impact, mitigation, and offsetting plans, as well as ways we are working with partners to decrease the impact altogether. It will also include an ethical framework and establish our role in action against space debris. We want to be part of the solution, not the problem.

Question: What do you think Spaceport Cornwall will be like ten years from now? What do you hope it will be achieving by then?

Melissa Thorpe: We have big ambitions here. There's already so much excitement and innovation happening in the county, and we will continue to work and collaborate to build upon this and put Cornwall at the centre of space exploration and responsible satellite launch globally.

We recently announced a partnership with our next operator Sierra Space. Their Dreamchaser system is an orbital return system, which will transport people and experiments to the ISS and bring research back down and land on our runway here in Cornwall. That might have people on board, and the value of what those people are doing is huge and we'll be able to process that in Cornwall. Our aim is to create a world-leading, sustainable, multi-user horizontal launch site in the heart of Cornwall, and to inspire communities and individuals to embrace STEM and the space industry and use it to benefit life on Earth.

Goonhilly state of the art network and mission operation centre.
Photo courtesy of Goonhilly



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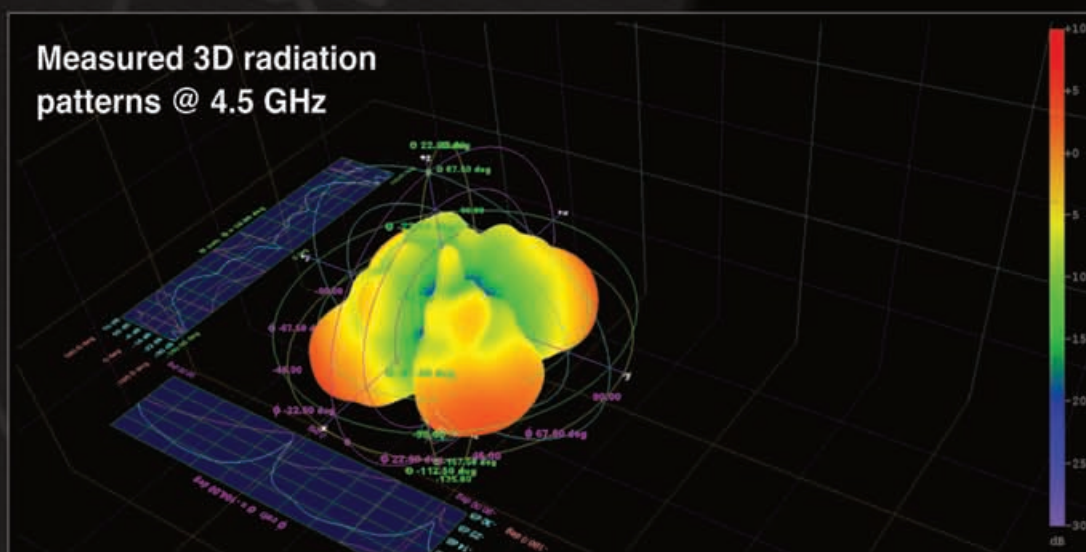
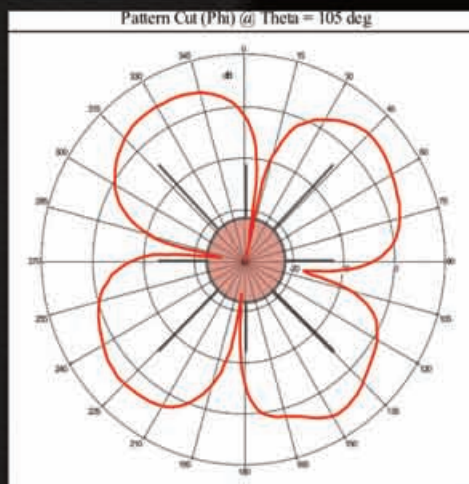
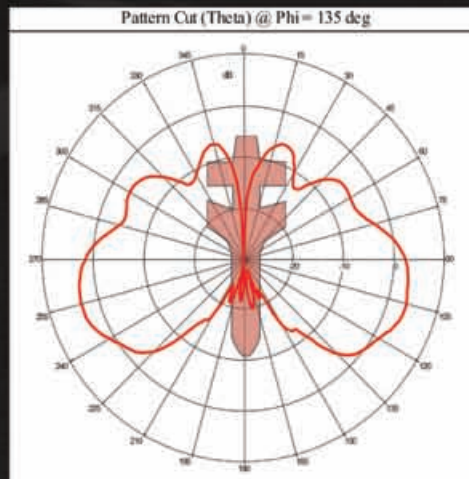
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Parameters	Description
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VSWR	< 1.5:1
Peak Gain	4.9dBi
Half-Power Beamwidth (HPBW)	Referring to results for detail
Polarisation	Linear Vertical
XPD	>30dB
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Connectorisation	RG188 Coaxial
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The future of rocket propulsion

There can be no spaceflight without propulsion. Its limitations are often the reason behind what we cannot yet achieve in space. With journeys to the Moon, Mars, and deep space an evergreen topic, and satellites increasingly being fitted with their own manoeuvring systems, fuel systems are getting more efficient, more innovative, and friendlier to the planet to match demand. Propulsion is a key to the space economy and the work of interstellar exploration.

Laurence Russell, Assistant Editor, NewSpace International

In a recently awarded contract announced 14 August 2021, Orbion was awarded a Phase 2 Small Business Innovation Research deal by the United States Air Force – as part of their AFWERX program – for 'El Matador,' a collision prevention feature that uses 'high-thrust propulsion to aid tiny spacecraft in avoiding collisions.'

Brad King, Founder and CEO of Orbion colourfully described the El Matador as a solution "allowing a spaceship to elegantly step out of the way and avoid the horns of an inbound threat."

The solution uses a high-thrust cold-gas nozzle integrated into Orbion's Aurora Hall-effect thruster for small satellites, allowing them to perform rapid repositioning manoeuvres, which they predict will become increasingly necessary as orbital space becomes increasingly congested in the next decade. Orbion's plasma propulsion systems boast high fuel efficiency and fast production times, the sort of electronic propulsion systems that are becoming increasingly ubiquitous with small satellites.

Greg Orndorff, Vice President and Business Development Lead at Orbion suggests the emerging requirements of satellites – ranging from repositioning, evasion, and de-orbiting as they end their service – may make reliable satellite propulsion a hard requirement for manufacturers.

The future of propulsion

Speaking exclusively to NewSpace International, Matt Villarreal, Co-Founder and CEO of Infinite Composites, agreed upon the sense of electrical propulsion in satellites. "Electronic propulsion is key for many deep exploration missions or satellites and spacecraft with long deployments, but the power required for launch and rapidity needed for quick transport is currently only realistic with traditional fuels. Hydro-oxygen and methane-oxygen propulsion will be the primary enablers for manned flights and colonisation efforts."

The work of outfitting spacecraft to support manned flight is a huge undertaking, eclipsing many of the technical challenges of space exploration. The added weight of life support and habitation systems alone requires careful consideration. Villarreal told us that it's Infinite Composites' job to do everything they can to reduce the mass that the propulsion system takes up –

since it can be the heaviest system on a rocket – in order to maximise the amount of weight that can be devoted to other critical systems.

"Strong propellant storage design is a big, missed opportunity for a lot of space companies. We're designing tanks that are more efficient, practical, cheap, and faster to produce, and that has a big impact when you add it all up," he explained. He hopes revolutions in propulsion system design can open doors for the space economy and the work of space exploration.

Another critical technology he defined for the future space economy was orbital refuelling, calling it "one of the keys both to going beyond Earth to reach the Moon and Mars reliably, but also to commercialising space in general."

He also applauded the work being done to establish how to produce fuel in space and off-world, which, while far-fetched, would be a pivotal step forward to realising the logistics of Mars and deep space journeys, which have often been considered too challenging to attempt with manned missions.

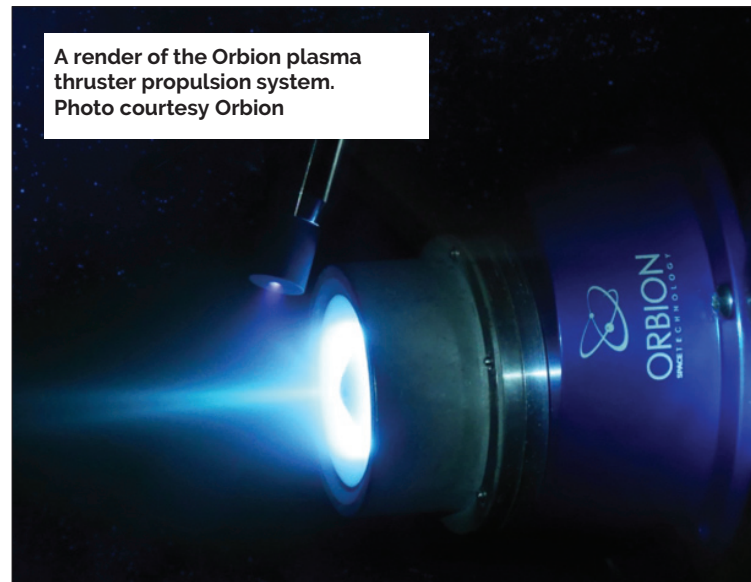
Villarreal takes the concept further, defining the capacity to manufacture spacecraft components in space via simplified designs and 3D printing production. "Infinite Composites are working on propellant tanks that can be produced by automated mechanisms through containerized manufacturing machinery that can operate in space or off-world."

Containerising production infrastructure capable of assembling specific parts as and when they are needed would be integral to maintaining the technology supporting a human presence in space in the long term. Though highly ambitious, such technologies could represent the foundation of our hypothetical Intersolar space economy.

Rocket eco-fuel and hydrogen

Villarreal also enthused about the importance of rocket eco-fuels which he defined as a clear priority in the launch market. He went on to highlight launchers continuing to use hyperbolics like hydrazine as the worst

A render of the Orbion plasma thruster propulsion system.
Photo courtesy Orbion



of the polluters when it comes to launch due to the toxicity of the chemical.

"I feel like hydrogen is the end-all-be-all solution for both Earth fuels and everything to do with space. Once we can get hydrogen fuels working reliably, it'll probably be a 'drop everything' moment. It's the most abundant element in the universe, and the best hydrogen fuels are just as capable as anything we use today. It could be both used in propulsion, but also burned for electricity like fossil fuels."

Hydrogen fuels could be produced as part of water desalination, a process for which experts predict humanity will have a great need for in the wake of the water crises they predict as one of many consequences of climate change.

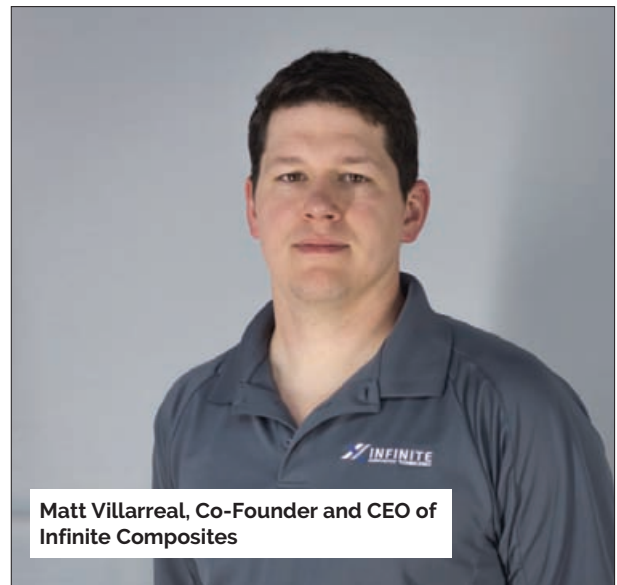
Of course, mass-producing hydrogen fuels is easier said than done. While entirely possible, the science needs to be affordable before it becomes a realistic replacement for fossil fuels. Airbus recently projected 2035 as the date by which they hoped to produce the world's first zero-emission commercial aircraft, currently known as their ZEROe concept hybrid-hydrogen aircraft.

In the meantime, other rocket eco-fuels can fill the gap.

Skyrora Ltd, a Scottish space company insists their high-grade rocket fuel Ecosene, manufactured by pyrolyzing unrecyclable plastics, could be a key disruptor of the fossil fuel economy.

The Ecosene process has been well-proven, capable of turning a ton of unrecyclable plastic into about 600kg of high-performance fuel suitable for rockets and commercial jet aircraft.

As both a cleaner fuel than Kerosene, due to its lower concentration of sulphur, and its supply chain, which is driven by the need to harvest plastic waste, investment



Matt Villarreal, Co-Founder and CEO of Infinite Composites

in Ecosene could provide a green stopgap for businesses relying on high-grade fuels as they await the hydrogen revolution.

Derek Harris, Business Operations Manager at Skyrora stated in 2019 that "reducing environmental impact in the space launch and aviation industries is about willingness to invest, rather than technological infeasibility. The technologies exist – companies and investors need to embrace them."

With propulsion such a key driver of our access to space, its advancement is a crucial pillar of the work that needs to be done. A work that already has paid off for fuel development on Earth. ■



Skyrora Engine test using Ecosene recycled eco-fuel. Photo courtesy Skyrora

Leveraging the potential of AI and edge computing in space

AI and edge computing on the edge of space could help organizations track everything from illegal shipping activity to climate change. The technology is ready and waiting on the construction of the frameworks in order to bring this innovative new step to reality.

Jeroen Cappaert, co-founder and CTO, Spire Global Inc.

The number of satellites in space is growing rapidly and with it, our ability to capture more Earth Intelligence (EI) data from the surface to near-space. Orbiting just above the Earth's atmosphere, today's small satellites provide comprehensive coverage of some of the world's most inhospitable regions – oceans, mountains, the Arctic and much more.

The availability of space-based services is certainly a game-changer for commercial and government agencies, who depend on quality data to spot adverse events and trends and make decisions. EI intelligence is for example being used to monitor melting sea ice in order to understand the impact of climate change or gain understanding of terrestrial and ocean ecosystems.

By monitoring sea ice, soil moisture, weather, changes that might once have gone undetected can now be identified in near to real-time and acted upon quickly – potentially saving countless lives and preserving fragile ecosystems. This data is not just valuable to governments monitoring the impact of climate change but also commercial organisations who want to optimize their trade routes.

Small satellites, orbiting the Earth as frequently as once an hour, allow organizations to track a plane or

vessel's every move and create a global snapshot of what's happening on the seas and in the skies. Activity that would once have gone undetected can now be identified in near to real-time and acted upon quickly – potentially saving countless lives and preserving fragile ecosystems.

Where EI data could be particularly valuable is in mitigating the impact of climate change. Floods, droughts, wildfires, hurricanes, and other extreme weather events are threatening human and animal populations and habitats globally, and the question of how we live with them is becoming more pertinent every day.

Since small satellites orbit the Earth more frequently than larger ones, they're able to capture data with the granularity required to transform current early warning systems. By applying predictive analytics and advanced forecasting tools to EI data, experts can identify unusual weather patterns and forecast the likelihood of a catastrophic event with greater precision.

As well as forecasting single events, insights derived from EI data helps experts to understand the impact of climate change over longer periods too, by mapping sea ice for example.

More data, faster speed

The volume of data generated by small satellite constellations is growing at a phenomenal rate – so much so that it's pushing data processing capabilities to the limit.

IT infrastructure constraints and a reliance on human analysts make it extremely difficult, if not impossible, for organizations to interpret EI data rapidly enough to support mission-critical decision-making. Ships travel quickly and planes that much more quickly, while changes in atmospheric pressure can occur suddenly and seemingly unexpectedly. Continuous scanning and low latency rates are therefore crucial if human activities and natural phenomena are to be tracked with accuracy.

Artificial intelligence (AI) and machine learning (ML) algorithms are already helping teams to process larger and more complex datasets, but the application of edge computing is key to reducing latency as datasets grow and become more complex. By processing data in orbit, it's possible to deliver real-time coverage of the Earth, while simultaneously alleviating pressure on bandwidth, ground stations and operatives.

Satellites, embedded with AI/ML modules, can significantly reduce latency with a combination of multi-sensor capture, more efficient cueing and tipping techniques, and by processing data using real-time data processing.

Last year, we launched our Brain in Space project with ESA's Earth Observation Science for Society Programme and Ö-lab to leverage machine learning, neural networks, and AI processing in space. Building on our proprietary computing platforms and AI/ML expertise,



Jeroen Cappaert, co-founder and CTO, Spire Global Inc.

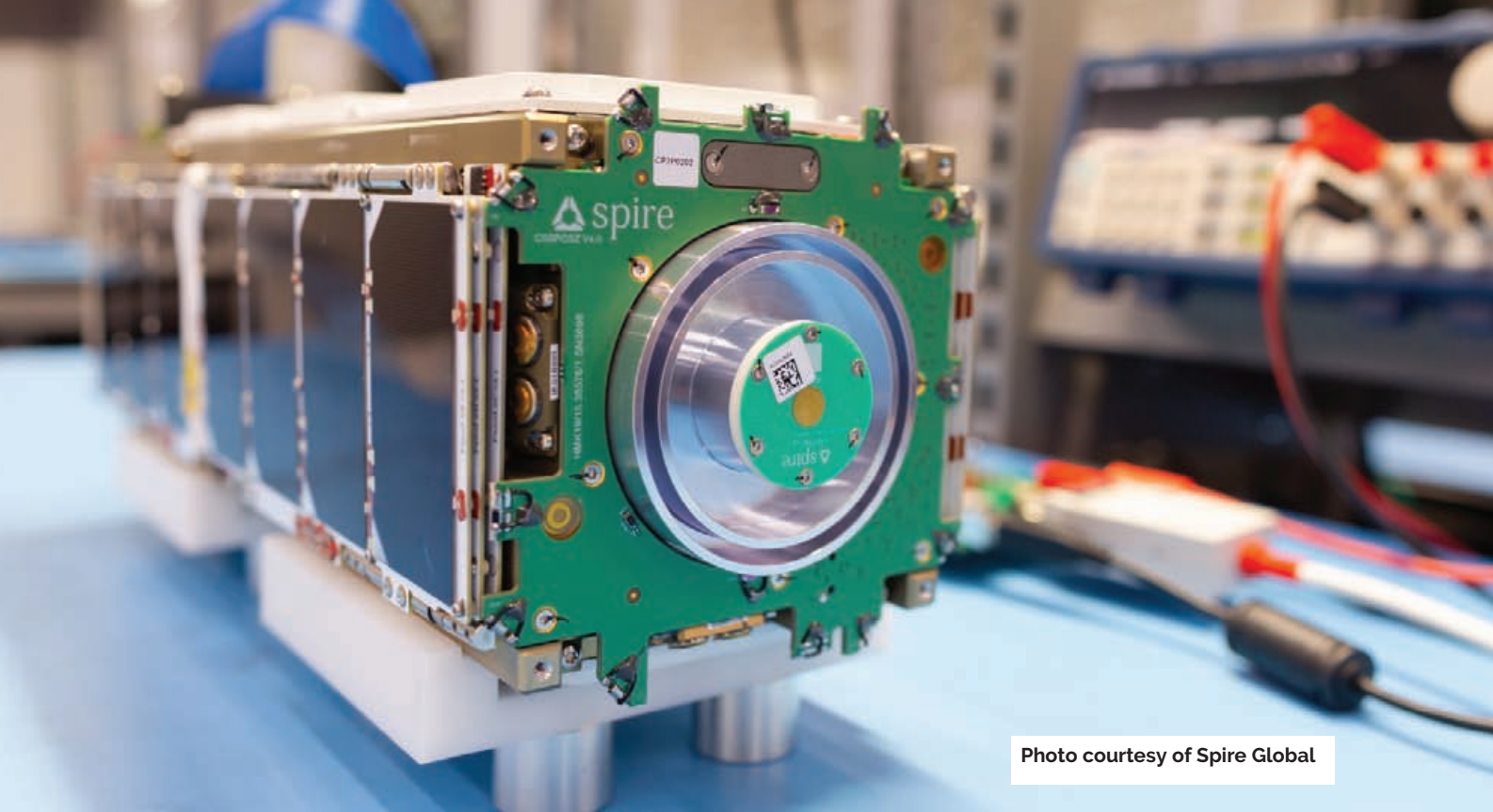


Photo courtesy of Spire Global

this testbed replicates Spire's LEMUR 3U platform, which supports our 110-strong nanosatellite constellation. Embedded edge AI and ML modules bring together signal processing and ML capabilities to autonomously detect and isolate patterns in large datasets at speed.

This testbed has been important for us internally because we can see how the new embedded edge AI/ML modules could unlock the potential of edge computing in space and make processing highly efficient. It's also been a useful steppingstone for other companies too. By making the testbed available to them, they've been testing out their own applications before committing to space-based services.

Processing in orbit is already a reality. The technology is there, it's just a case of building the frameworks and having the data available.

Space for the real world

NewSpace has opened up the possibility of space-based analytics to more organizations, enabling them to solve challenges in the real world. The sector has benefitted from a wave of tech innovation already seen in other industries, including AI/ML and the electronics miniaturization already used in autonomous vehicles, drones, and smartphones.

We've now reached a critical juncture. Despite rapid developments in cloud computing, processing space data may still be too slow and expensive for private firms in particular to see the value of it. This is why edge computing in space is such a powerful proposition and is in fact essential if insights are to be delivered fast enough. To put the timescales into perspective, Naeem Altaf, distinguished engineer at IBM and Space Tech CTO, estimates that data could be analyzed in 'hours instead of days' using edge computing.

Looking ahead

Collaboration between governments is going to become even more important if they are to tackle major threats such as climate change and international security, both now and in the future. They'll need to be able to share

data securely and coordinate activity efficiently, and which is why I see huge potential for increased AI and edge computing technologies applied in space.

We work closely with technical teams, usually in government bodies, to prove that their space-based projects work before handing over the steering wheel.

The new raft of innovations, including the application of edge computing in space, is only going to drive up demand for space-based analytics in the commercial world too. But these companies are not always interested in looking under the hood. It's hard to believe, but not everyone thinks that space is as cool as we do: They want applications to integrate seamlessly with theirs, so they gain real-time insights that drive performance and deliver value in the shortest time possible. ■



Offering an edge in the race to space

With constellation services continuing to flesh themselves out, the most competitive business cases remain up in the air. As providers struggle to provide the best service at the lowest cost, Dennis Silin, CEO at Exodus Orbitals, introduces a new satellite-as-a-service solution, proven by the Moonshot accelerator program, which could offer an edge.

Laurence Russell, Assistant Editor, Satellite Evolution Group

Question: Exodus Orbitals has recently graduated from the 12-week Moonshot program. What did that involve?

Denis Silin: Moonshot is an Australian business incubator for companies in the space sector and other emerging niches. We have worked with their team that included Moonshot founder Troy McCann and other mentors and angel investors through a very intense 12-week boot camp, participating in workshops on every part of company operation, including sales, marketing, pitch deck and technology readiness review.

The finale of this program was showcasing our pitch to the audience of potential investors and in the Moonshot network. We also have Moonshot to thank for our pre-seed funding.

Question: Exodus Orbitals was one of five businesses that successfully graduated from the Moonshot accelerator program from a pool of eleven hopeful companies. What set you apart?

Denis Silin: What set us apart was both the novelty of the idea of satellite-as-a-service (SaaS) and our level of traction on both technical and business fronts. We have been working with ongoing space missions to validate our technology, from as early as December 2019 with the European Space Agency.

We had also received real customer commitments for our first commercial satellite, planned for launch in 2022. Many space start-ups don't expect their first space launch and first revenue to happen for many years to come, but this is not the case with us. Some of the companies dropped out of the Moonshot business accelerator program for a variety of reasons, but we persisted and participated until completion.

Question: Exodus intends to "make space exploration more accessible" for businesses across all sectors with its satellite-as-a-service platform - Could you expand on that service?

Denis Silin: With Exodus Orbitals, anyone will be able to launch their own app into space and control their space mission with a software development kit (SDK) and deployment pipeline. Effectively, the businesses that had no experience or budget to operate their own



Dennis Silin, CEO at Exodus Orbitals

satellite fleet would get access to space through our platform, by using our 'satellite-as-a-service' platform and assisted by our 'pay-per-use' pricing model.

We will provide sufficient hardware capabilities to run most of Earth observation and surveillance business cases in low Earth orbit (LEO) and our customers can then implement their own application and deploy it to the satellite the same day. This model is very similar to what modern cloud computing infrastructure providers, such as Amazon AWS, offer to their customers on the ground.

Many of our potential clients already consume data from satellite operators but have no ability to run their analytics directly on the satellite. Moving the algorithms closer to the source of data can massively improve the amount of value of downlinked data as it can be processed more deeply. For example, instead of just raw imagery, a list of labelled and georeferenced objects can be streamed to the ground.

In a similar manner, instead of raw radio frequency recording, a list of transmitters, their types and locations can produce via an on-board application for the customers. There are plenty of interesting opportunities that can benefit from onboard data processing, including running machine learning (ML) algorithms on imagery and signals data. We plan to include support for hardware acceleration for inference and (later) learning stages of ML applications.

Question: You explain the platform will lower costs for businesses making use of satellite applications. What is the potential for a satellite market with dramatically lowered barriers for entry?

Denis Silin: It is hard to predict what can become possible if millions of small and medium companies will gain access to space on par with the biggest industry players. One thing can be stated with confidence – the number of new applications will explode exponentially, and the size of the market as well. To be more specific, hyper-local satellite applications (single neighbourhood or municipality, single farm, single shipyard and so on)

is one field we expect to grow. There is enough maturity in the satellite hardware realm, with hundreds of different instruments and sensors already in orbit. But all the software tools and deployment pipeline developers take for granted in mobile or web application domains are not available at the same level of access and flexibility in the satellite industry. We plan to fix this drawback and make 'single-click access to space' a reality. Imagine the growth of Internet-powered or smartphone applications repeated in the space industry, on a proportionally large scale!

Question: How are you able to provide such affordability where your competitors can't?

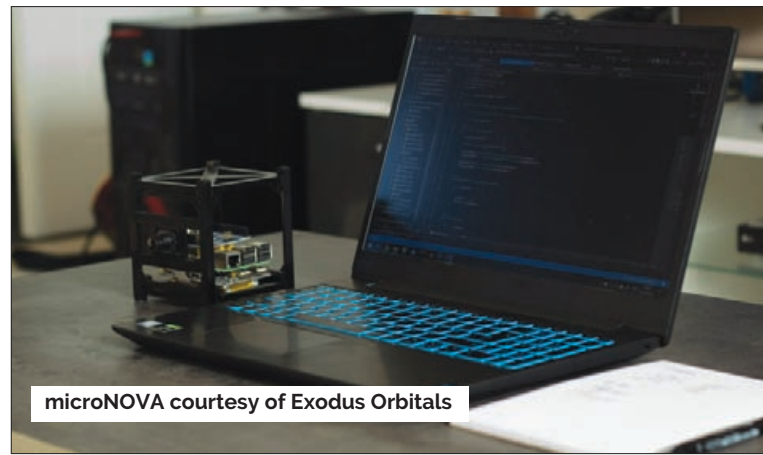
Denis Silin: Right now, implementing any kind of space technology is assumed to be a capital-heavy, risky, and time-consuming affair. By switching to a leasing model both for our customers and for building up our platform capabilities, we can reduce upfront capital requirements and cut down on development time by orders of magnitude.

We plan to lease existing and future satellite assets, offering our partners a share of the revenue from our customer base. At the same time, our customers will get access to a diverse array of space-based instruments, something that no single company can offer. Being a 'software in space' company we can reduce the costs of our technology development. Our priority right now is the integration of existing satellite hardware into our platform, while our satellite partners can focus their efforts on innovations in sensors and instruments.

Question: You've been quoted comparing the potential of the space industry to the technological revolution of terrestrial web and mobile connectivity. Could you expand on the potential for innovation that you see?

Denis Silin: Space fundamentally is another green field for the global economy, however currently it lacks most of the infrastructure we have on Earth. Think of power stations, manufacturing plants, markets, communication networks or community centres.

While many space startups are already building 'hardware' parts of the future infrastructure like space stations, refuelling and repair depots and communication relays, we are building the platform to



support the 'software' part of space infrastructure - application hosting providers, online marketplaces, electronic stock exchanges or network domain registrars.

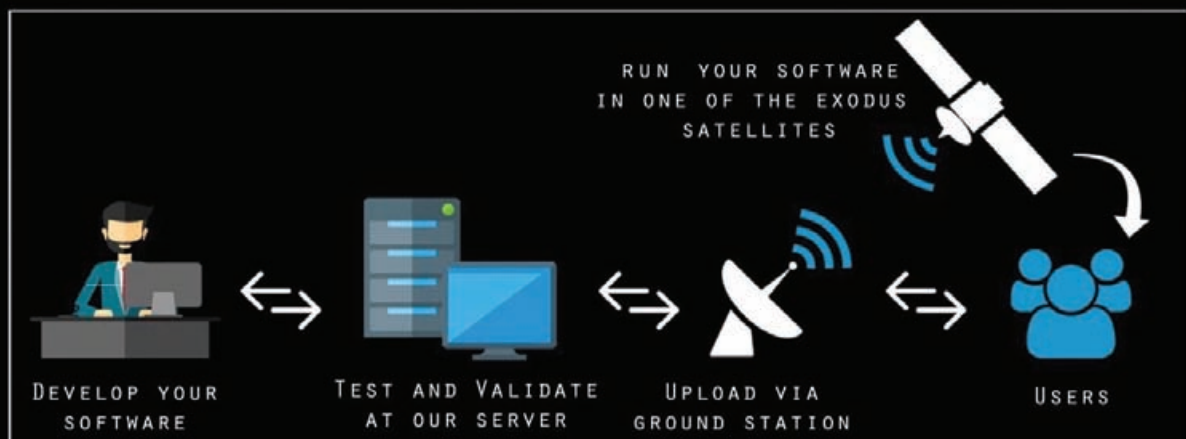
Using our software to connect the 'hardware' assets in space into an interoperating network multiplies the number of potential applications that can utilize these assets compared to isolated and independent satellites operating in stand-alone mode.

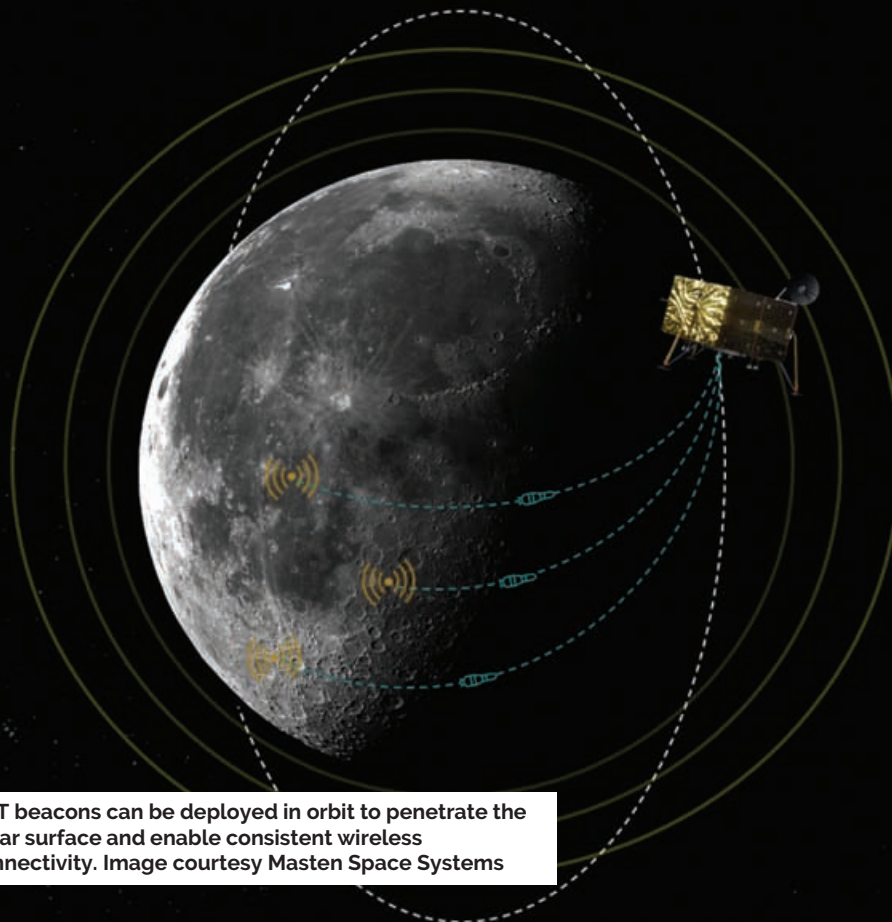
Question: We've seen experts suggest that many emergent technologies such as 5G, smart city applications and cloud computing may lean heavily on the support of satellite applications in the near future. Could you comment on your confidence in the maturation of those markets driving satellite ROI?

Denis Silin: Right now, it is a question of matching pricing model with increasing demand for in-space capabilities for those applications. It is not cost-effective to launch a dedicated satellite for every smart city project but sharing a single satellite for multiple such projects through our platform is an effective way of doing so.

On the other side of our approach, it will be possible to combine multiple physical satellites into a single 'virtual satellite.' That will allow customers on the ground to create new applications that better support their business cases. We plan to accelerate this trend to the 'satellite for every household' level of market penetration a reality in a few years and not in a few decades, driving up the ROI of investment into our platform hundredfold. ■

Exodus infographic





--- Lunar orbit
--- Beacon deployment
--- Wireless connectivity

PNT beacons can be deployed in orbit to penetrate the lunar surface and enable consistent wireless connectivity. Image courtesy Masten Space Systems

Masten

Connecting to the Moon and beyond

As mankind edges ever closer towards an intergalactic future, with space tourism already being brought to reality earlier this year, assured, reliable connectivity off-world is a vital component of our future. With secure world-to-world communications, travellers between planets can better achieve their goals.

Amy Saunders, Editor, Satellite Evolution Group

Currently a matter for science fiction, deep space communications for parties travelling through space to the Moon, Mars and beyond, will certainly require reliable, secure communications between the spacecraft and Earth. With the ambitious plans of our current batch of billionaires – Musk, Bezos, and Branson – it's looking increasingly likely that the first manned interstellar trip may well take place during our lifetime.

The only entity to date with an advanced established Deep Space Network (DSN) is NASA, which operates the largest and most sensitive telecommunications system in the world in order to support its off-world missions. The DSN is operated by NASA's Jet Propulsion Laboratory (JPL) and consists of three facilities spaced equidistant from each other around the Earth some 120 degrees separated in longitude – at Goldstone, California, near Madrid, Spain, and near Canberra,

Australia. The placement enables constant communications between spacecraft and Earth even as the world rotates.

The antennas at the three DSN sites – which are indispensable for commanding spacecraft remotely and receiving data and images from missions – require regular upgrades to maintain reliability. Earlier this year, the Spanish site welcomed its newest addition, the Deep Space Station 56 (DSS-56) dish, a new 34m antenna. The new antenna is a Beam WaveGuide dish which required a more complex commissioning phase than its predecessors due to its novel nature of being the first 'all-in-one' antenna capable of communicating with all missions/probes that use the DSN. All other DSN dishes have limited frequency ranges, meaning they cannot communicate with every mission. That changes with DSS-56, which utilizes the DSN's full range of communication frequencies. This has an added benefit of allowing the new dish to serve as a backup for any of the Madrid complex's other antennas regardless of the mission they're talking to. A fifth 34m dish, again with the same 'all-in-one' antenna, will join the Spanish site later this year.

"The Deep Space Network is vital to so much of what we do – and to what we plan to do – throughout the solar system," said Thomas Zurbuchen, NASA Associate Administrator of the Science Mission Directorate. "It's what connects us here on Earth to our distant robotic explorers, and, with the improvements that we're making to the network, it connects us to the future as well, expanding our capabilities as we prepare human missions for the Moon and beyond."

The Moon's first LTE/4G system

Possibly the first modern network expected to come to fruition on the Moon is Nokia Bell Labs' LTE/4G solution. Back in 2020, Nokia released further details on being

selected by NASA to deploy the first LTE/4G communications system in space, which will help pave the way for a sustainable human presence on the Moon. The local network, which will extend around 5km to allow communications between astronauts and equipment on the lunar surface, is a low-power, space-hardened solution is expected to be deployed by the end of next year. Nokia is partnering with Intuitive Machines to integrate its ground-breaking network into their lunar lander for delivery to the Moon's surface.

The network will provide critical communication capabilities for many different data transmission applications, including vital command and control functions, remote control of lunar rovers, real-time navigation and streaming of high-definition video. These communication applications are all vital to long-term human presence on the lunar surface.

Nokia's LTE network is ideally suited for providing wireless connectivity for any activity that astronauts need to carry out, enabling voice and video communications capabilities, telemetry and biometric data exchange, and deployment and control of robotic and sensor payloads. The network will consist of an LTE Base Station with integrated Evolved Packet Core (EPC) functionalities, LTE User Equipment, RF antennas and high-reliability operations and maintenance (O&M) control software. The solution has been specially designed to withstand the harsh conditions of the launch and lunar landing, and to operate in the extreme conditions of space. The fully integrated cellular network meets very stringent size, weight, and power constraints of space payloads in an extremely compact form factor.

The same LTE technologies that have met the world's mobile data and voice needs for the last decade are reportedly well suited to provide mission critical and state-of-the-art connectivity and communications capabilities for any future space expedition. LTE is a proven commercial technology, has a large ecosystem of technology and component suppliers, and is deployed worldwide. Commercial off-the-shelf communications technologies, particularly 4G, are mature, proven reliable and robust, easily deployable, and scalable. Nokia plans to supply commercial LTE products and provide technology to expand the commercialization of LTE, and to pursue space applications of LTE's successor technology, 5G.

GPS on the Moon

Something we take for granted here on Earth as an essential for everyday life – particularly if, like me, you can live somewhere for five years and still be incapable of navigating further than a 15-minute walk from your home without Google Maps – but which is proving so vital for lunar exploration that we're already seeing multiple planned projects, is an accurate, reliable positioning system installed on the Moon.

August saw the US Air Force Research Laboratory's AFWERX programme award a Phase II Small Business Innovation Research (SBIR) contract to Masten Space Systems to develop and demonstrate a lunar positioning and navigation network prototype. With functionality similar to GPS, the network will enhance cislunar security and awareness by enabling navigation and location tracking for spacecraft, assets, objects, and future astronauts on the lunar surface or in lunar orbit. As the lunar ecosystem grows, the network will also help

advance lunar science and resource utilization by improving landing accuracy and hazard avoidance near critical lunar sites.

In Phase I, Masten completed the concept design for the network prototype that offloads position, navigation, and timing (PNT) beacons from a spacecraft into a dedicated sensor array on the Moon. In Phase II of the project, scheduled to be complete in 2023, Masten will develop the PNT beacons that are equipped to survive the harsh lunar environment. Masten is collaborating with Leidos to build shock-proof beacon enclosures that can be deployed in lunar orbit to penetrate the lunar surface and create an autonomous surface-based network. Similar to a mesh network, the surface-based network can enable consistent wireless connectivity to lunar spacecraft, objects, and orbital assets. In Phase II, the PNT technology will also be tested aboard Masten's rocket-powered lander, Xodiac, to demonstrate payload integration and beacon operations in a terrestrial environment, enabling a path towards lunar demonstration.

"Unlike Earth, the Moon isn't equipped with GPS so lunar spacecraft and orbital assets are essentially operating in the dark," said Matthew Kuhns, Vice President of research and development at Masten. "As a result, each spacecraft is required to carry heavy navigation hardware and sensors on-board to estimate

Photo courtesy of Shutterstock



positioning and detect potential hazards. By establishing a shared navigation network on the Moon, we can lower spacecraft costs by millions of dollars, increase payload capacity, and improve landing accuracy near the most resource-rich sites on the Moon."

Another positioning project was announced a little earlier in May; the European Space Agency (ESA) announced plans to build a telecoms and positioning network around the Moon utilising a constellation of satellites. Under Project Moonlight, which aims to accelerate lunar research efforts, two consortia are working in competition.

SSTL leads the first consortium with a Phase A/B1 Study into the Moon telecoms system, in collaboration with SES Techcom, Airbus, Kongsberg Satellite Services and the Goonhilly Earth Station. A second consortium led by Telespazio will study the architecture of the Lunar Communication and Navigation Services, working with Thales Alenia Space, Inmarsat, MDA, Telespazio's subsidiary in Germany, OHB Systems, Hispasat, the Italian Aerospace Logistics Technology Engineering Company (ALTEC), Argotec, Nanoracks Europe, the Politecnico Milano and the Università commerciale Luigi Bocconi.

An initial three or four-strong satellite constellation around the Moon is envisaged, alongside small base stations on the surface to be used to hone positioning. With the use of radio astronomers and lunar rovers, the far side of the Moon could also be effectively opened up. ESA hopes the network will be interoperable with NASA's planned LunaNet.

LunaNet

With the Moon the first target for off-world exploration in the years to come, the delivery of assured, reliable communications between the lunar surface and Earth are essential.

Entirely distinct from the Nokia LTE/4G system, NASA

is also aiming to establish a relay communications and navigation architecture called LunaNet to make it easier for lunar devices to communicate with each other and with Earth. Much like the Internet on Earth, LunaNet would enable communications among robotic landers, rovers, scientific devices, and astronauts, and also allow them to transmit data back to Earth through Moon-orbiting relays, such as satellites, smallsats or a Moon-orbiting space station. Provided each network node can relay data to its immediate neighbour, the LunaNet architecture can be assembled from a variety of infrastructure systems, independent of frequency band, type of spacecraft or provider. LunaNet's multi-hop relay network could be accessed from anywhere on the Moon by surface or orbiting devices, provide direct access to Earth stations when required and supporting high-definition video for multiple users.

LunaNet is expected to include three categories of services:

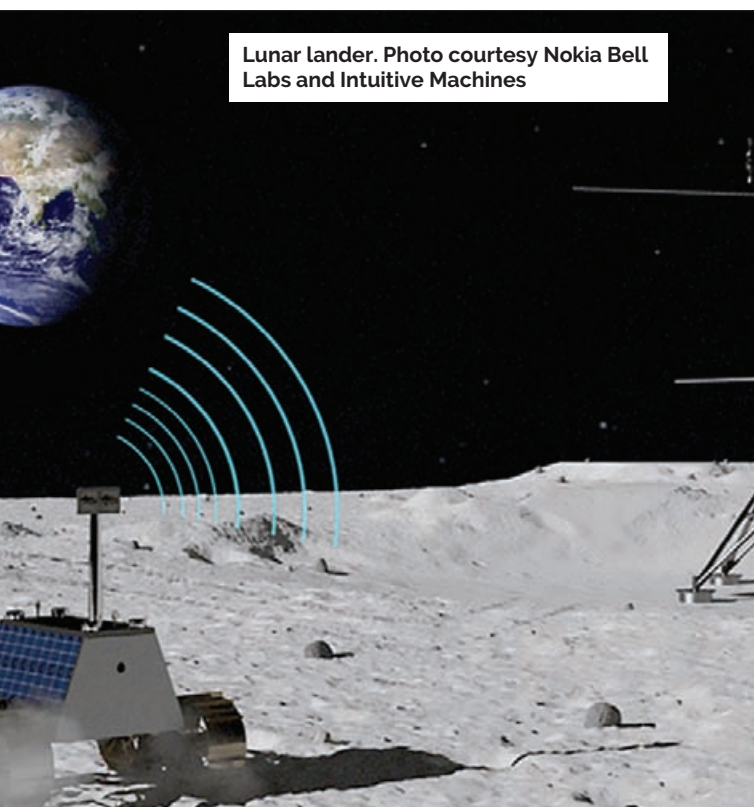
- Networking services capable of moving data between nodes that adhere to confidentiality, integrity, and availability requirements
- Position, navigation and timing services for orientation and velocity determination, as well as time synchronization and dissemination. These services could be used for search and rescue, surface navigation and location tracking
- Science services providing situational alerts and scientific measurements that could not only further research, but also support predictions of major solar eruptions that affect space weather and provide information about space radiation

NASA anticipates many advantages to a relay navigation system. LunaNet would be critical for communications during deliveries of science payloads to the far side and polar regions, where direct communication with Earth ground stations will be impossible without a relay. For manned missions to the South Pole, having a relay satellite in an appropriate orbit would allow for more flexibility in mission scheduling and landing site selection and would provide more options in contingency situations. NASA's communications with rovers would be easier because LunaNet would be much closer to lunar vehicles, shortening the distance signals must travel and allowing the use of smaller, less powerful transmitters and receivers. Orbiting spacecraft, especially small satellites, also would benefit from precise timing and position information readily available from LunaNet.

To provide reliable service for the Artemis missions in 2024, LunaNet would have to be operational well in advance, so NASA wants the technology ready for operation no later than 2023.

An intergalactic future

Considering just a small handful of the ongoing off-world communications projects of today serves to exemplify that the future of humankind is, indeed, intergalactic. And we're not just talking about the distant future either – Nokia Bell Labs' LTE/4G system is due online next year, while LunaNet is expected just one year after. With the rapidly accelerating space travel capabilities we're witnessing right now, these off-world communications networks are indeed much needed in today's world. ■



Lunar lander. Photo courtesy Nokia Bell Labs and Intuitive Machines



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The progress of NASA's Artemis missions and the commercialization of the moon

Our lunar missions have a history of being understood as sensational achievements overshadowing all other achievements beyond our planet. With many long-awaited Moon missions entering execution in the 2020s, including a manned journey, expectations are high. Recent NASA strategies to incorporate commercial operators could be a sign of a new culture in the world of space exploration, though it hasn't come without challenges.

Laurence Russell, Assistant Editor, NewSpace International

At this year's Space Symposium in Colorado, NASA updated the industry on their ambitions to establish an orbital lunar outpost, otherwise known as the 'Gateway,' serving as a staging area for Lunar surface missions, featuring habitation modules facilitating manned missions.

Part of the program includes the pathfinding CubeSat mission 'CAPSTONE,' a hefty acronym for Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment, which is set to fly in mankind's first cislunar orbit, developed by NASA's Small Business Innovation Research (SBIR) awards. More specifically, CAPSTONE will fly in a near-rectilinear halo

orbit, which uniquely factors the gravity of Earth. The project is intended to reduce logistical uncertainty for Gateway, and the NASA and international partners utilising it.

Unfortunately, the previous US Administration demanded a manned mission occur by 2024, which forced NASA to de-prioritize the Gateway, which led to a scheduling strain that increased collaboration with private enterprise to aid development, including commercial launchers, primarily SpaceX.

These manned missions have also been delayed due to issues with Artemis' new spacesuits, also produced by NASA commercial partners. Speaking on the delay, Senator Bill Nelson, NASA's 14th Administrator echoed President John F. Kennedy's famous remarks at the 36th Space Symposium 2021, declaring "we choose to return to the moon not because it is easy, but because it is hard. We can do hard things. We are a can-do people."

A recent NASA audit stated in clear terms that "a lunar landing in late 2024 as NASA currently plans, is not feasible." This, combined with Blue Origin's lawsuit squabbling over federal launch contracts has crippled the progress of the missions, representing a definite downside to the privatisation of space, showing that billionaire enterprise may not be prepared to take no for an answer when it comes to laying claim to taxpayer money at the expense of innovation and human achievement.

The Gateway project, and Artemis' long-term vision

Though de-prioritized, Gateway is fortunately designed with a modular layout that can accommodate incremental construction, spread across a number of phases, meaning it can accommodate delays better than other space exploration projects.

In addition to manned missions, the Artemis program will involve a rover experiment in the Lunar South pole in order to search for a sample of the region's infamous water deposits, hidden in its eternally dark craters. If successful, the rover will also be equipped to determine the water's composition.

These craters of eternal darkness have been highlighted as sensible locations for Lunar colonies, due to the natural protection of the surrounding rock, sheltering colonists from a modicum of regolith and solar radiation.

The presence of water could potentially be utilised, too. Indeed, many theories of future Lunar colonisation missions intend to save payload space by utilising as many Lunar materials as possible.

"Space resources will play a key role in NASA's Artemis program and the future of space exploration," explained Senator Bill Nelson at the Symposium. "We



Sen. Bill Nelson, 14th NASA Administrator addresses the 36th Space Symposium in early 2021. Photo courtesy Space Symposium

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will make cement from [Moon regolith], eventually, and thus we can build habitats that way, by using not earthly dirt, but lunar dust. ... The ability to extract and use extra-terrestrial resources will ensure Artemis operations can be conducted safely and sustainably in support of human exploration."

Lunar business cases

In a conversation with Chuck Gray, VP and COO of Frontier Electronic Systems, NewSpace International discussed the potential for sustainable business cases on the Moon. Gray identified lunar transportation, sustainment, and mineral process industries as the standout drivers, all of which NASA has taken early steps toward monetizing through partnerships with space companies.

The demand for space exploration is a fine one, though the very real demand for lunar resources is another conversation. Our planet is facing a rare Earth metals crisis which has very few long-term options for mitigation. Eventually, strict electronics recycling systems and deeper mines will not be able to answer the demand. In the future, we may need to rely on off-world gold, cobalt, and thorium for the technologies of the future.

Of particular interest to several space agencies are the Moon's surprisingly abundant Helium-3 reserves, which have bombarded the lunar surface on solar winds for aeons, leaving a veritable treasure trove of the isotope. It is speculated that the Moon's helium-3 deposits could fuel lunar nuclear energy, as well as support the transition toward carbon-neutral energy generation on Earth.

On a more realistic timescale, the Artemis missions require cutting-edge technology in order to be successful. "Lunar missions require very sophisticated

power control, safety and habitation systems," Gray explained. "The highest possible efficiency is needed here. Ultimately, we'd like to work out how to deliver a self-sufficient set of interdependent systems with replaceable parts which themselves are simple enough to manufacture for repair on-site."

The Moon will also represent a valuable staging area in the solar system for future deep-space missions, ensuring the relevance of Lunar investment as humanity establishes an ever more expansive space economy over the 21st century.

Gray also went on to corroborate the risks to human space habitation, acknowledging the dangers of solar radiation and reduced gravity on the human body, but he substantiated the pioneering spirit he had come to understand from entities in the new space race, who were eager to rise to the challenges of the final frontier.

"I look at human exploration as comparable to the historic exploration of the Americas. It's an opportunity to venture into the unknown. There's a lot of passion to go beyond what we know, to embrace a new state of human civilisation."

NewSpace International also approached Craig Smith, Director of the Oklahoma Space Industry Development Authority (OSIDA), who has enjoyed extensive experience working with Oklahoma Air and Space Port, which plans to one day host horizontal take-off and landing for space missions.

Smith described the idea of establishing a Lunar transportation hub as "the ultimate goal of every spaceport." With spaceports sprouting up all over the planet and the space economy establishing itself more firmly every decade, we can only expect the market share to grow. Over our lifetimes, we may find ourselves witnessing profit being drawn from space in ways we might never have imagined. ■



Tulsa University Researchers work with Frontier Electronics on space-capable lithium ion batteries. Photo courtesy of Frontier Electronics/Tulsa University



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