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Mission Microwave: Developing revolutionary products

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Q&A Francis Auricchio, President and CEO, Mission Microwave

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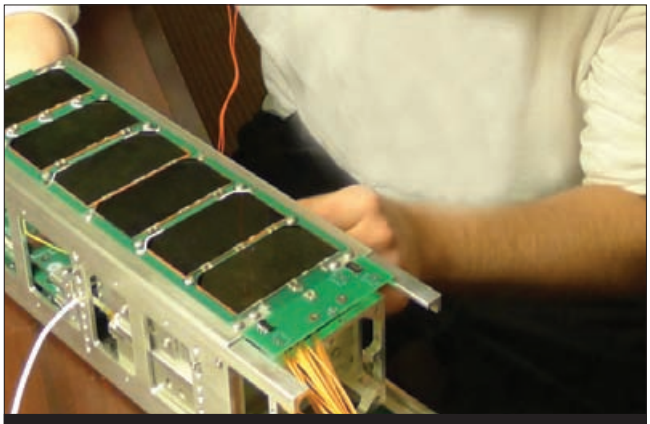


Satellite design for long life, high speed data management and connection. See page 28 ●●●

Front cover photo courtesy of Von Lewis Photography

Space tourism. See page 32 ●●●

Telesat to receive US$1.44 billion in Canadian Government investment

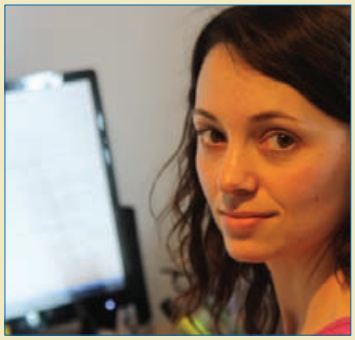
Telesat has announced that it expects to receive a US$1.44 billion investment from the Government of Canada to support Telesat Lightspeed, the world's most advanced low Earth orbit (LEO) satellite network. This investment will drive economic growth and innovation in Canada and help ensure affordable broadband Internet and LTE/5G connectivity for all Canadians.

Under the terms of the agreement, the Government of Canada would provide a loan of US$790 million and make a US$650 million preferred equity investment in Telesat Lightspeed. In return, Telesat will commit to make certain minimum capital and operating expenditures in Canada in connection with the program and, in addition, to create hundreds of Canadian high-quality, full-time jobs and co-ops and provide academic scholarships. Through Telesat and its Canadian supply chain, the Telesat Lightspeed program is expected to support over 1,500 Canadian jobs, largely in STEM.

Telesat Lightspeed is the largest space program ever conceived in Canada and will be the most innovative, cutting-edge broadband satellite network in the world. The Telesat Lightspeed network is initially comprised of 298 highly advanced satellites with next-generation technologies to deliver multiple Gbps speeds and fibre-like connectivity everywhere in Canada and across the globe.

"Now is the time to bolster Canada's position as a global leader in the new space economy," said The Honourable François-Philippe Champagne, Minister of Innovation, Science and Industry. "Through its partnership with Telesat, our government is creating more high-skilled jobs, enabling innovation and helping to unlock economic and social opportunities in Canada's most rural and remote communities. Every Canadian should have access to affordable high-speed Internet. Today, we took a big step towards making that happen."

EDITOR'S VIEW



Making it rain

We're halfway through the UK's annual heatwave, which means that the weather is well and truly on the minds of the masses. Admittedly, our definition of a heatwave is most likely laughable to those in the Middle East, Africa, Americas, Asia, Australasia, and Southern Europe – reaching heights of around 32°C – however, in our defence, UK homes do not come equipped with the air conditioning typical of much of the world. Many homes do not even contain a fan.

Admittedly, the UK heatwave is nothing compared to the typical heat of summer in Australia, the Middle East, Africa, etc. Nor is it comparable to some of the freak weather we've been seeing lately, including the June heat dome in the Pacific Northwest. The heat dome pushed temperatures well above 40°C in some areas, and as high as 50°C in others. The Pacific Northwest is accustomed to much more moderate temperatures, thus the extreme weather resulted in loss of life – current estimates are around 500 - severe damage to infrastructure and is estimated to have killed around 1 billion marine animals on the Canadian coast alone.

Tackling extreme weather in the UAE, an interesting experiment has just taken place. A new form of weather modification technology, scientists have used drones to fly into clouds and distribute electrical charges – an act called 'cloud seeding' - to 'cajole them' into clumping together to produce rain. One of the most arid countries on Earth, and currently holding steady at an eye-watering 50°C, experts in the UAE hope to use the technology to improve upon the low levels of annual rainfall. The experiment has been hailed as a huge success, with the drones prompting monsoon-like downpours across the country, with drivers struggling to navigate the roads.

The effectiveness of cloud seeding for increasing overall rainfall is still under question, with much of the scientific community doubting that it makes a noticeable impact. However, other forms of cloud seeding technology (not drone-led) have been utilised at ski resorts in Colorado to reduce heavy snowfall, and ahead of the 2008 Beijing Olympics to create rain elsewhere and keep the stadium dry.

Trying to distract ourselves from the heat, in this issue, we've interviewed Fran Auricchio from Mission Microwave Technologies to learn more about the company's culture, philosophy, and market expectations in these difficult times. We've also spoken with Rogue Space's Jeromy Grimmett about the company's on-orbit spacecraft servicing solutions. Richard Swardh from Comtech EF Data outlines the evolution in radio access networks (RAN) and implications for the satellite industry, while Omnetics' Bob Stanton has shared his thoughts on space-based circuit design. Roman Buff from HUBER+SUHNER opines on the key to leading in the NewSpace race. Meanwhile, we've explored the fantastic leap forward in commercial spaceflight achieved in July with the first commercially crewed launches by both Virgin Galactic and Blue Origin, and the latest developments in on-orbit satellite servicing.

Photo courtesy of Shutterstock

US Space Force awards Orbital Services Program (OSP)-4 contract to emerging small launch providers

The US Space Force's Rocket Systems Launch Program Office, a part of the Space and Missile Systems Center's Launch Enterprise at Kirtland Air Force Base, Albuquerque, New Mexico, announced the award of the first on ramp of the Orbital Services Program (OSP)-4 Indefinite Delivery/ Indefinite Quantity (IDIQ) contract to ABL Space Systems Corp, Astra Space, Inc., and Relativity Space, Inc.

OSP-4 allows for the rapid acquisition of launch services to meet mission requirements for payloads greater than 400 pounds, enabling launch to any orbit within 12-24 months from task order award. The RSLP will compete each mission among the IDIQ awardees. The addition of these emerging providers' preserves, stimulates, and enhances the small launch industrial base and yields the Space Force a diverse vendor pool in support of the nation's defense.

"This program utilizes a low-barrier-to-entry to mature launch providers and those emerging companies that are approximately one year from being launch capable," said Lt. Col. Justin Beltz, chief of Launch Enterprise's Small Launch and Targets division. "We use this IDIQ contract to continue to introduce speed, agility, and flexibility into the launch enterprise and continue to cultivate a resilient and affordable launch market."

The SMC Launch Enterprise initially awarded the OSP-4 contract in October 2019, to Aevum, Firefly Black, Northrop Grumman Innovation Systems, Rocket Lab USA, Space Exploration Technologies Corp., United Launch Alliance, VOX Space, and X-Bow Launch Systems. This on ramp will add additional emerging launch providers to the group eligible to compete for future USSF OSP-4 Task Order awards.

The US Space Force previously awarded two missions on OSP-4 with the Space Test Program-S28 mission to VOX Space and Tactically Responsive Launch-2 mission to Northrop Grumman, and expects to procure approximately 20 missions over the nine-year ordering period. The Launch Enterprise projects awarding the next task order supporting the Space Test Program's USSF-46S mission later this summer.

Developing revolutionary products

Mission Microwave Technologies is a developer of revolutionary solid-state power amplifiers (SSPAs) block upconverters (BUCs) to support terrestrial, airborne, and space-based applications with a sizeable client base. Francis Auricchio, President and CEO, shared his thoughts on the company's road to success, and how Mission Microwave views its industry.

Laurence Russell, Assistant Editor, Satellite Evolution Group

Question: Mission Microwave is a relatively new company with a history of rapid growth over the past four years. What's the secret to the company's success?
Fran Auricchio: We decided very early on that we weren't going to try to be a one size fits all company with a wide catalogue of products to satisfy every need. We've seen other companies do this and it typically results in mediocre products or empty promises. When we first started Mission, we had this idea that if we could only make this one product that is smaller, lighter and more efficient than anything on the market, customers would flock to us.

Francis Auricchio, President and CEO, Mission Microwave. Photo Von Lewis Photography ●●●

SatTV video interview ●●●

We developed a prototype of this revolutionary product – the Ku-band Javelin – within six months, and I hand carried a mock-up of it to the IBC Show in Amsterdam in 2014 to see customer reactions.

The reaction was universally consistent; customers felt that the product was indeed revolutionary – but almost all said that while this was great, they wanted to see a lower power level. While they were thrilled with the new product, it didn't match their immediate need and therefore wouldn't sell as we anticipated. Armed with customer feedback, we went back to the drawing board and developed the smaller product that they were looking for; the Ku-band Stinger. This was both revolutionary and met demand.

Being the new kid on the block created some challenges when selling against products that had almost a decade of history in the industry. Some of our competitors stoked the fires of concern with our customers, saying that if the product were that small and light, it couldn't be reliable. We had such confidence in our product though that we invested in demo units and gave them to our customers to try out, so that they could experience it for themselves. Those initial demos brought in some extremely valuable feedback from customers which we incorporated into our next generation of the product.

We wanted this to be our core product and really optimized the internal components for performance, reliability and manufacturability. The products improved over time and as we started to seed the market with these Stinger products, customers started asking what else we were working on. The acceptance was great because the product performed the way we said it would and the size, weight and power (SWaP) advantages were compelling reasons for customers to switch.

Because we had been listening to our customers, we knew that they had an interest in other frequency bands, so we embarked on developing a Ka-band version of the Stinger, to create a family of products with similar sizes, shapes and interfaces to enable our customers to easily offer multiband terminals. Thinking ahead, we tried to make the product features seamless so that customers wouldn't have to totally

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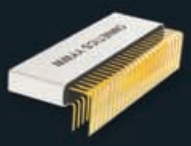

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re-engineer their terminals to offer other frequency bands. Likewise, we used this modular approach to give customers the same performance for the lowest power amplifier in the band to the highest power levels, using the same components. With the components the same, the performance and reliability are consistent throughout the entire product line. This was a key factor to customers embracing Mission Microwave's products and ultimately the secret to our success.

Question: What are the toughest challenges that come with expedient growth? What are the most satisfying milestones?

Fran Auricchio: One of the toughest challenges has been letting go. In start-up mode, it is expected that you wear every hat and do everything, but as the company grows, you find people who can be trusted to take on some of your tasks. However, with increased growth, it becomes harder to find people who think like you and will do things just like you. Can they do the job? Yes. Will they do it just like you do? Probably not. Rationalizing that someone can do the job differently and still be successful is a hard hurdle to overcome, but it must be understood for the company to scale.

There are a few exceptions to this: Quality and reliability. These are standards that must be met and if that means following a scripted process in order to achieve it, then this now becomes a process instruction. Failing because processes are not being followed and everyone wants to do things their own way is unacceptable. When a customer purchases a Mission Microwave product, they expect the performance, quality and reliability to be the same as the last one and the next one. Searching for candidates, not just the perfect ones, but the ones that we feel can do the job correctly, has been one of the hardest parts of the job.

> "We wanted this to be our core product and really optimized the internal components for performance, reliability and manufacturability. The products improved over time and as we started to seed the market with these Stinger products, customers started asking what else we were working on."

On the satisfaction side of the equation, seeing the company grow from 10 to 25 employees to 50 employees and even higher has been tremendously satisfying. We are not just employing 70 employees; we are providing for 70 families.

When COVID-19 hit in March 2020 and we had to send everyone home, we were in a panic; not just because of the impact this could have on our business, but the impact it would have on our employees and their families. Thankfully, we came up with a plan to keep non-essential personnel working offsite while the essential personnel could report to work and be provided all the protection necessary to keep them safe. As a result, not one employee was affected by COVID-19 in 2020 and all employees retained their employment and Mission's operations continued to function. I am extremely grateful to our employees who trusted us to keep them safe and continued to work every day throughout the crisis.

Mission Microwave headquarters. Photo Von Lewis Photography

Ka family - Stinger, Javelin and Titan model BUCs. Photo Von Lewis Photography

Another rewarding milestone has been the level of customer acceptance of Mission products. At the 2019 Satellite Show, Mission Microwave had its products prominently displayed in 14 customer applications. This was a phenomenal cross-section of the industry and far more than our closest competitor.

Question: In today's turbulent markets, what gave you and your co-founders the confidence to build a company from scratch?

Fran Auricchio: After the acquisition of our previous company, we stayed on for three years, continuing to grow the company. As what happens in most transactions of this nature, the now new parent company wants to take control and do things their way, which is understandable.

At first, there was a collaborative effort in introducing some of these changes, but the collaboration eventually stopped, and we were being told how to run the business from our foreign parent. At some point you say to yourself; if the discretion to perform our jobs as we see fit has gone away, isn't there a better use of our talent?

We struggled with this for a while but with the emergence of new semiconductor technology, we thought we could do something different with it. The thought of leaving a stable job, having to raise money and start all over again was scary and exciting at the same time. Investors would ask us this question all the time when we were pitching the idea: "So how is this different than what you were doing before?" We would respond that we are excited about using this new semiconductor technology and have some interesting ideas on how to exploit its benefits. Most investors couldn't see our vision, but we found some that could, and Mission Microwave was on its way.

One change that we were desperately seeking was the ability to develop out of the box approaches. Having been in this business for almost four decades, I have seen a lot of copying what is known to work, adding a feature, putting your own spin on it and calling it a new product. We did not see this as a path to success, so we were willing to break the mold, literally.

Mission's flagship products feature a cylindrical form factor, which is quite different from the rectangular boxes that the industry has been used to seeing. We even had this debate internally about whether to pursue this, as some would believe it is a 'sexy' gimmick to put the same old hardware in a futuristic package and call it revolutionary. When we would inform customers of the benefits, they could then see that this was more than just a packaging gimmick and the odd shape really did offer unique advantages. The journey has had its twists and turns but we are happy to say that our vision has been successful.

Question: A company's culture and its treatment of customers comes from the top-down. Where did Mission Microwave learn its philosophy?

Fran Auricchio: Over the course of my career, I have worked for people that have either made you feel like you were part of a family or a cog in a wheel of a large machine. It is obvious which one we prefer, and I try my best to instill that feeling of

Mission Microwave has focused on being the top solid-state power amplifier producer in the world by doing one thing; only producing solid-state power amplifiers (SSPAs). Photo Von Lewis Photography

family throughout the organization.

With about 70 employees, both domestic and international, I can proudly say that I know all of these employees by name. Some of these employees have worked with me or for me for almost 30 years and have followed me from company to company. I have always said that if you treat your coworkers with respect and share an interest in their success, they will go out of their way to ensure that you are successful. This loyal base owns the success of Mission Microwave, as they were the ones that helped build it.

I see this inner employee attention as being very similar to customer attention. Most customers want a partner, not a supplier. A partner is with you during your ups and downs; not being happy to hear from you when you are ready to place an order and doesn't want to talk to you when you have a problem. A customer with a problem is a reflection on you as a partner, so we'd better make sure that whatever issue is resolved as quickly as possible, with the least impact to the customer, even if it means replacing the hardware.

Your customer can be your biggest cheerleader when they talk about how you bend over backwards to help them and how satisfied they are with your products and customer service, or they could be the source of a black eye when they don't speak highly of you or tell others how you've let them down. Mission has customers that are still amazed that when they call, the CEO will follow up on the response. This personal level of attention, when through the CEO or any of Mission's employees is a foundation of Mission's customer service.

Question: The satellite industry is a niche of the broader aerospace and defence industry, and RF manufacturing is a small niche within that segment. What are some of the challenges that come with that focus and how have you and your team met them?

Fran Auricchio: Mission Microwave has focused on being the top solid-state power amplifier producer in the world by doing one thing; only producing solid-state power amplifiers (SSPAs). Some companies have a portfolio of products, of which the SSPAs represent a small percentage of their overall business. Our entire company is dedicated to designing and producing SSPAs, which narrows our focus and allows us to do that one thing very well.

I have been asked why Mission doesn't 'move up the value chain' and build more of the terminals we support. The answer is simple: We are in business to support our customers as a partner, not a competitor. Mission is an enabler to help our customers transform the satellite industry through innovative

Ku Stinger 55W. Photo Von Lewis Photography


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products that span a variety of markets. Once we step out of that box and start replicating some of the work that our customers do, we become a competitor. Once that customer loses that trust that we can keep their business plans confidential, we can no longer be of value to them to produce highly integrated products and allow them to differentiate themselves in the market.

A growing percentage of Mission's work is along those highly integrated lines and this effort could force our customers to seek partners elsewhere. By retaining our narrow focus of only building amplifiers, Mission has instilled confidence in our customers, and they continue to work closely with us to develop custom solutions for their terminal projects.

Question: What can Mission Microwave's customers expect in the future?

Fran Auricchio: This question is a little hard to answer in an open forum without revealing proprietary business information, so I must keep it very high level. Mission Microwave continues to increase the power level of its product offerings, to even include some TWTA replacements.

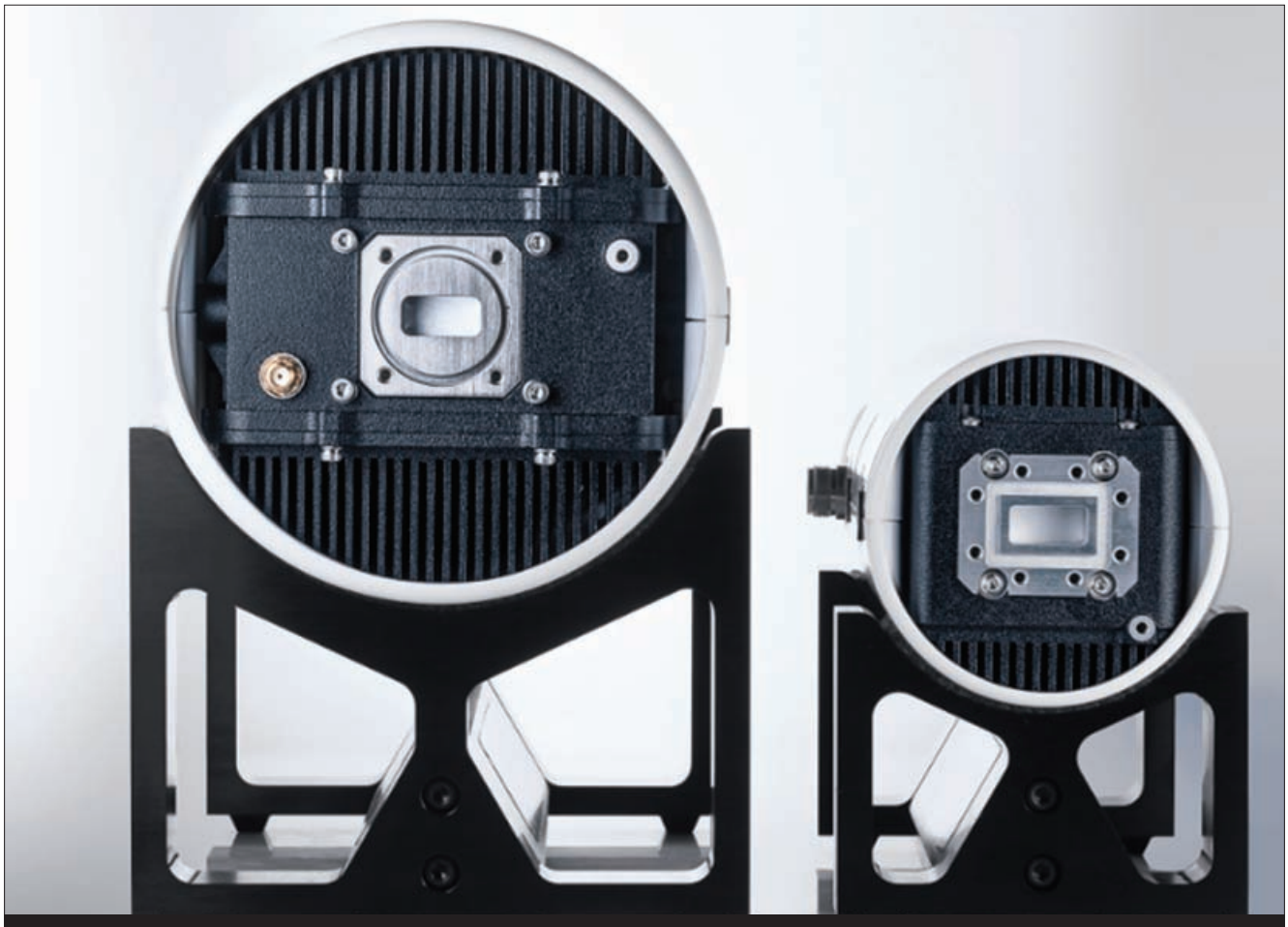
These products will offer customers solid-state performance and reliability for those traditional tube applications. Mission is expanding its portfolio of airborne products, having completed multiple DO-160 certifications.

"Mission Microwave has focused on being the top solid-state power amplifier producer in the world by doing one thing; only producing solid-state power amplifiers (SSPAs). Some companies have a portfolio of products, of which the SSPAs represent a small percentage of their overall business."

We are also expanding our product offerings for the satellite gateway market. Although you may not be able to see our handiwork from the outside, customers are confident when it has Mission Microwave on the inside.

Mission Microwave will continue to look at higher frequency bands for solid-state products. At this point, it may be premature to start talking about solid-state for Q-band and V-band, but we continually get asked whether we are working on it. We will continue to assess the market and when the time comes, Mission will have a compelling solid-state solution.

Customers can continue to expect the same partnership focus with Mission Microwave, with a focus on performance, quality and reliability. As Mission continues to grow, we will not lose that focus and will be pleased to offer our customers the best possible products and customer service – from the CEO down to all levels in the organization.



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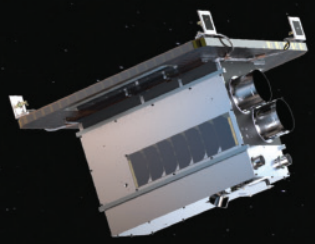
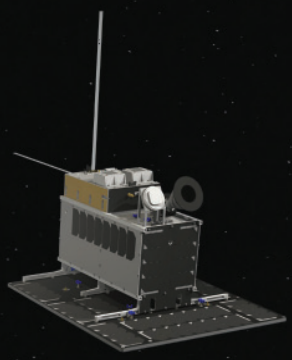
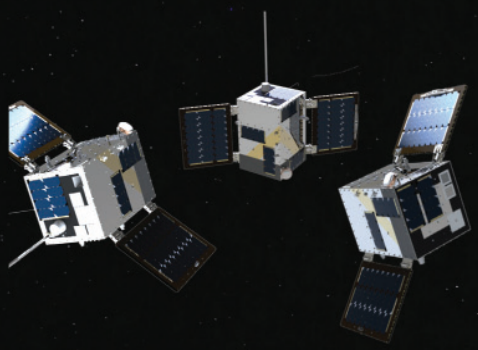
Distinct missions launched, under construction or ready to launch



DMSat-1 Microsatellite
Launched March 22, 2021



NorSat-3 Microsatellite
Launched April 28, 2021



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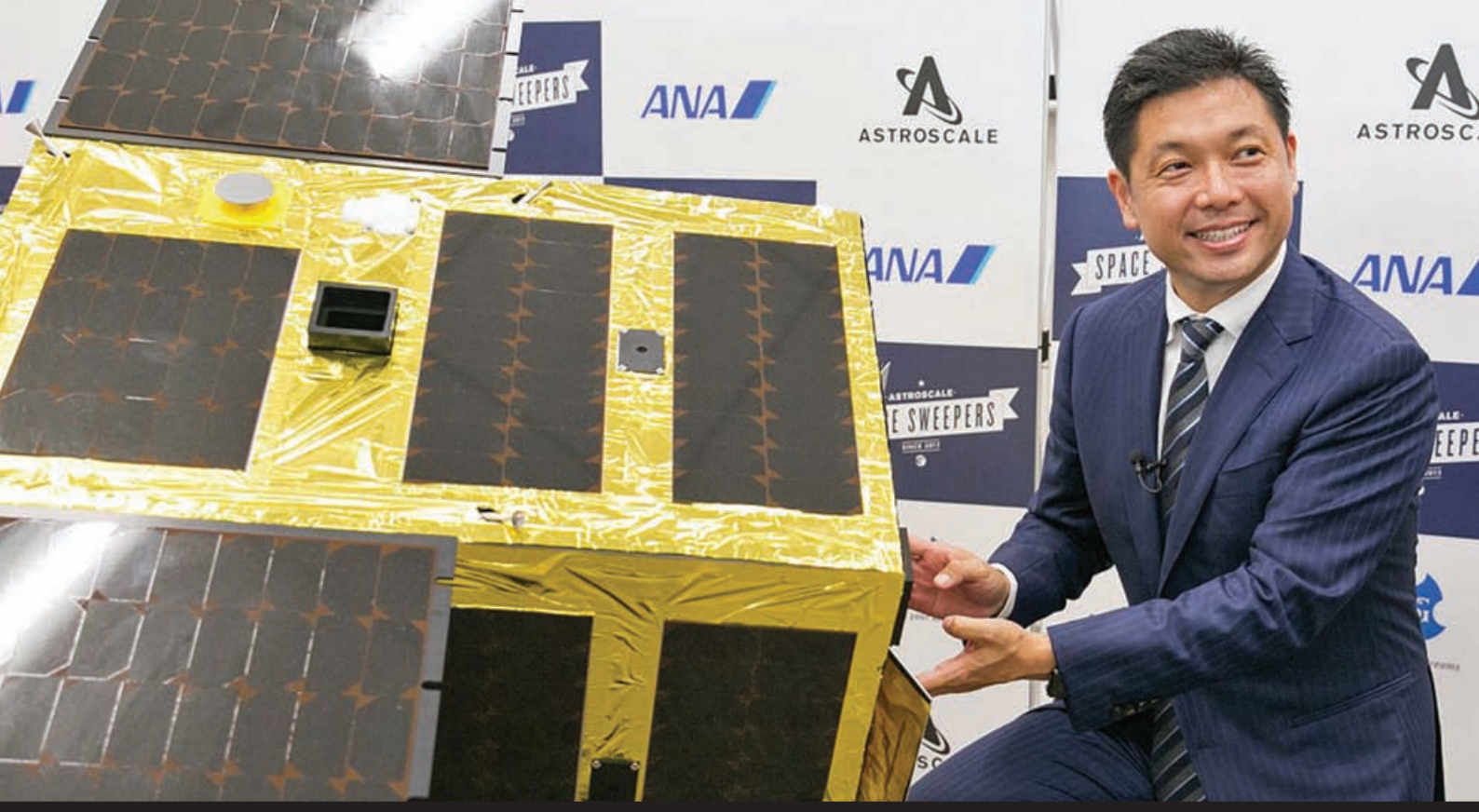

Astroscale Founder Nobu Okada poses with a replica of the company's ELSA-d demonstration vehicle. Photo courtesy Astroscale

In-orbit servicing

In-orbit servicing has been actively producing demonstrable results for its technology in practice, creating business cases and ensuring the longevity of its enterprises. As one of the more futuristic and exciting fields in the space economy, the fledgling market moves fast, making for some fascinating developments.

Laurence Russell, Assistant Editor, Satellite Evolution Group

On 1 February, NSR called the in-orbit satellite servicing and space situational awareness markets a US$6.2 billion opportunity, assuming their expectations for the growing market were met. As a relatively difficult market to judge given the uncertainty of its service offering, business cases, and solutions, which are all still very much theoretical, in-orbit servicing is a volatile and obscure market to judge too critically.

Regardless, progress has been made to bring the opportunity to life, as new agreements, programs, and experiments are announced.

Astroscale/Mitsubishi collaboration

In late July, Astroscale signed a memorandum of understanding with Mitsubishi Heavy Industries to cooperate on active debris removal and space environmental protection via in-orbit servicing technologies, which is the first of Astroscale's long-term partnerships with a launch provider.

"Active debris removal and robotic technologies are paving the way for on-orbit services that will form the infrastructure of the global space economy," said Nobu Okada, Founder & CEO of Astroscale. "Astroscale is leading the on-orbit servicing market and providing options, which have not been available until now, for satellite and launch vehicle operators to reduce risk and increase ROI."

The small company has been the recipient of state funding via Japan's Ministry of Economy, Trade, and Industry (METI) for the development of space-ready robotics for complex servicing procedures in lunar and orbital environments. More specifically, this research involves the development of robotic articulation, and the automation of such processes, as well as component replaceability of those solutions, allowing for the servicing units themselves to be easily serviced. The funding is expected to support lunar base construction activities as part of Japanese contributions to the international Artemis space exploration program.

Mitsubishi's rocket development and launch services could help Astroscale develop the kinds of next-generation solutions it needs to maintain an edge in the in-orbit servicing market. Initial priorities for the partnership include the development of solutions for removing upper-stage rocket debris.

"We are very pleased to take action with a leading global launch provider on debris removal and move the industry toward a more sustainable future," said Takayoshi Koyama, Managing Director of Astroscale Japan. "To secure sustainability in space, we must address both the prevention and remediation of debris. At Astroscale, we are doing both and are dedicated to improving the space environment by leading the development of innovative on-orbit servicing solutions across all orbits."

With the assistance of METI funding, Astroscale is expected to develop more elaborate servicing technology, capable of extending satellite life and reducing operating

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costs, thereby preventing the creation of new debris for existing operators and launchers, perhaps leading to the development of the kind of all-in-one servicing craft becoming increasingly discussed: A space tug.

Space tugs

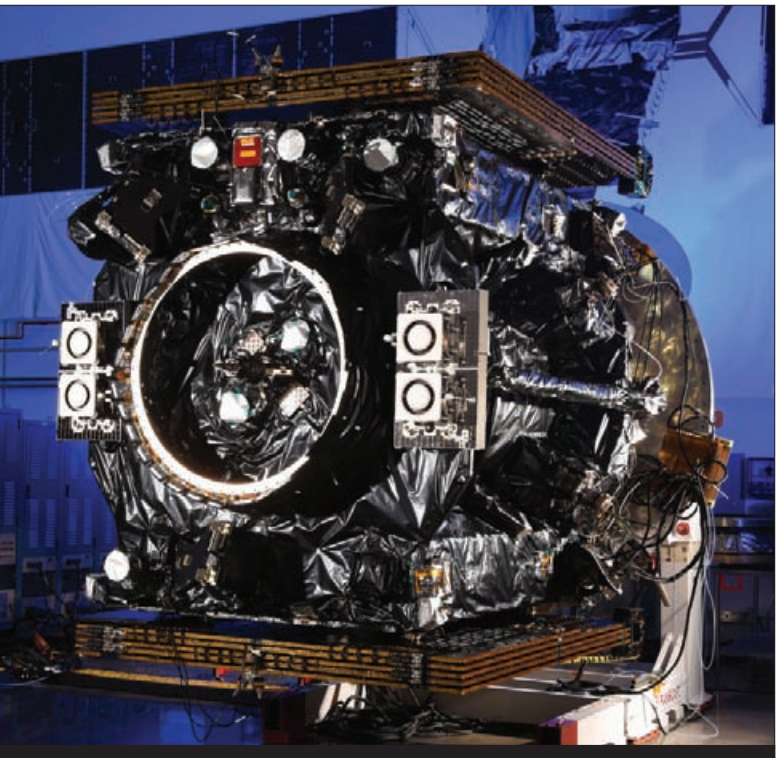
The advent of the orbital transfer and servicing market appears most evident in the development of 'space tug' machines - orbital craft designed to maintain, refit, reposition, and de-orbit satellite and spacecraft to more actively sustain space investments and the environment they rely upon.

As increasingly critical orbital requirements are explored, scrutiny increases in the field of space sustainability, and satellites are constructed with longer lifetimes, the need for orbital craft that can suit these demands has gained momentum.

It's understood that the first tugs will start small, performing inclination or altitude adjustments, though as their capabilities are proven, and investment solidifies, these services will soon grow into a more elaborate portfolio of interchangeable applications.

Landmark achievements such as the mission extension procedure by Northrop Grumman, Astroscale's ELSA-d deorbit demonstration, and a last-mile positioning delivery by D-orbit have all proved that the theory of in-orbit servicing holds water in action, leading some to predict exponential growth as myriad demands are recognised and addressed.

The nitty-gritty of how servicing platforms such as this will monetize in the future continues to be debated, with some suggesting subscription models for the operators they serve as well as traditional one-off service fees. Deorbiting services will be marketed to owners of derelicts, though state funding could drive the clearing of additional junk belonging to bankrupt, disbanded, or even uncooperative parties.



Northrop's MEV 2 vehicle in storage before its launch. Photo courtesy Northrop Grumman

Fears that dedicated orbital services entities won't be solvent on their own has also led to predictions that the brave startups demonstrating such technologies will be consolidated into other launch companies. This may be the scenario that Astroscale has been courting with Mitsubishi Heavy Industries. With so much in space markets still unproven, and setbacks all but inevitable, there is still much to be done to assure business confidence.

Luckily there are complimentary solutions underway with the explicit purpose of bringing safety and simplicity to high-risk space operations.

ESA's mission control AI

ESA intends to support the development of a range of in-orbit servicing technologies too but recognises the logistical challenge that an effective market would present. Mission control and tracking services already have their hands full keeping track of launches and satellites. A set of craft native to orbital spaces also in operation would require additional oversight to ensure its effectiveness and precision.

A valuable and ultimately necessary measure to orchestrate all this work is sharing information and pooling organisation into a hub that can monitor everything and take direct control of the platforms.

The European Ground System—Common Core (EGS-CC) is intended to serve as the future nerve centre of all European spaceflight operations, including forthcoming in-orbit servicing efforts and the operation of autonomous craft. While the system intends to aggregate controls of European and possibly other Western platforms, it creates a precedent for more extensive collaboration, perhaps across nations of different power blocs, between which many near-miss incidents have occurred, many averted by chance.

Existing ESA missions are already being prioritized for adoption into the EGS-CC from 2025 onward, when all missions will be operated via the multi-mission control system, which uses artificial intelligence (AI) and machine learning (ML) tools.

The EGS-CC was first used on 26 June 2021, taking responsibility for ESA's OPS-SAT space lab so to demonstrate its capacity to monitor and control the satellite, successfully sending a set of routine commands to the craft while collecting mission data.

"This has been a hugely successful validation of this new versatile control system," said Klara Widegard, EGOS-CC Project Manager. "Demonstrating the exciting future of mission control technologies and Europe's leading position in space."

Rolf Densing, Head of ESA's ESOC Operations Centre echoed his colleague's sentiments: "At its heart, this new software marks an important step in bringing to life the space technologies of the future. Close cooperation between space agencies and industry has made this possible, opening up opportunities for all space entities in Europe to fly exciting, innovative and important missions through space."

Though the in-orbit servicing market holds the potential for breakout success, it also possesses the potential for the kind of compounding setbacks and eventual loss of momentum that we saw in the field of asteroid mining, for which several well-funded startups rose and fell, leading to something of a radio silence on the matter. As solutions develop and prove themselves, the market remains one to watch.

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Collaboration. Photo courtesy of Istockphoto

Open RAN – What is it and will it impact the satellite industry?

The evolution in radio access networks (RAN) towards an open architecture, supported by the O-RAN Alliance, has enabled increased opportunities, and streamlined the ecosystem for everyone active within it. There exist some excellent lessons to be learned by the satellite industry, although the unique challenges render a carbon copy model impossible.

Richard Swardh, Senior Vice President, Premium Enterprise & Mobile Operators, Comtech EF Data

The mobile industry is undergoing a massive transformation that may have significant implications on the satellite industry down the road. As deployments and momentum behind 5G is continuing to build, so too is a whole new ecosystem of hardware and software developers of emerging mobile networking equipment that come from a different background than the traditional telecommunications world, with a deep-rooted belief in support of open-source practices, cross industry collaboration and cloud infrastructure as a vehicle for rapid innovation and commercial success.

In the roughly 40-year long history of cellular communication, the mobile network operator (MNO) market was initially developed by PTTs and some truly visionary entrepreneurs like Craig McCaw in North America, Jan Stenbeck in Europe, Sunil Mittal in India. This helped form companies that are familiar to many of us today such as AT&T Wireless, Vodafone, and Airtel. The vendor ecosystem that initially developed and helped bring technologies like GSM and D-AMPS to market has also some names familiar to many of us – Alcatel, Ericsson, Lucent, Motorola, Nokia, Nortel, and Siemens. The market grew beyond the wildest expectations at the time and moved from a business luxury to an essential part of everyday life for the population at large. Now, with more than five billion subscribers globally, the pressure to constantly innovate and deliver equipment and services at a lower cost is always present. The ever-increasing demand for R&D and cost efficiency lead to a massive and sometimes painful consolidation in the mobile infrastructure industry while two new entrants from China entered the markets, as well. Today, the radio access network (RAN) market is basically dominated by Huawei, Ericsson, and Nokia, with ZTE being a distant fourth. Many of the original equipment vendors either merged, went bankrupt or exited the market due to lack of acceptable returns on investment.

Consolidation of the RAN vendors was driven to a large degree on request by the MNOs as they grew in size and power, entered new markets and started to run multiple mobile standards in parallel. This increased complexity

significantly and MNOs needed bigger partners that could take on a greater responsibility end to end, scale up R&D and manufacturing and deliver the cost savings and spectrum efficient solutions that drives the MNO business forward. While this enabled MNOs to consistently deliver a greater EBITDA for service providers than the RAN vendor community had enjoyed, there is a global trend that is causing concern among some MNOs. The geopolitical landscape over the last few years has developed in a direction where new barriers are being put up and free access to technology is being restricted. Chinese vendors are being locked out from many markets in the name of national security and access to chipsets that are an essential part of RAN equipment is also being restricted through tighter export regulations put on chips that include American intellectual property rights (IPR). This has led to MNOs in some markets only having access to two major vendors for their mobile infrastructure needs - this is a concern among many procurement officers that favour diversity and choice.

An open marketplace

As a consequence of having fewer choices and supply constraints, many MNOs and RAN vendors look favorably on several initiatives that are well on their way to develop a more open, flexible, and competitive marketplace for hardware and software used for radio access network equipment.

The first important step on this journey was defined by 3GPP in Release 15 when they split the base station between a distributed unit (DU) and a central unit (CU). This allowed for virtualized RANs or cloud-based RANs to be deployed with pooling and sharing of hardware resources using a combination of commercial off-the-shelf and proprietary hardware. Software code for RAN functions can run virtualized using a combination of proprietary software, third party commercial software, and open source. Open RAN architecture aims to further disaggregate hardware and software as specified by 3GPP. The O-RAN Alliance is developing specifications to complement 3GPP by defining interface profiles, additional new open interfaces and new nodes. An example of this work is from the Telecom Infrastructure Projects OpenRAN project group that defines the OpenRAN reference architecture with three different elements with clearly defined and open interfaces between them:

There are a handful of new functional splits for RAN specific tasks defined that can be designated to the three main building blocks. One example of a functional split defined by O-RAN consists of the RU (Radio Unit) that handles the lower layer 1 functions (some PHY/RF). This unit is located at the cell tower next to the antenna. Then there is the DU (Distributed Unit for some PHY, RLC/ MAC/PDCP) along with the CU (Central Unit) being the interface towards the Core Network. Both DU and CU can be co-located and lend itself well to sharing and pooling of resources leading to a very cost-effective solution with a low total cost of ownership (TCO) and an ideal option for a distributed RAN deployment.

Disaggregation means a move away from the monolithic solutions traditionally offered by existing RAN vendors using a tight and proprietary dependency between hardware and software to a fully open and interchangeable and vendor neutral general-purpose platform, also called white box-based platforms, with interchangeable software.

The goal of the proponents of Open RAN is to challenge and enhance the existing vendor ecosystem and introduce supply chain diversity, flexibility and rapid innovation across the technology stack applying for instance building practices that have been prevalent in Cloud infrastructure deployments

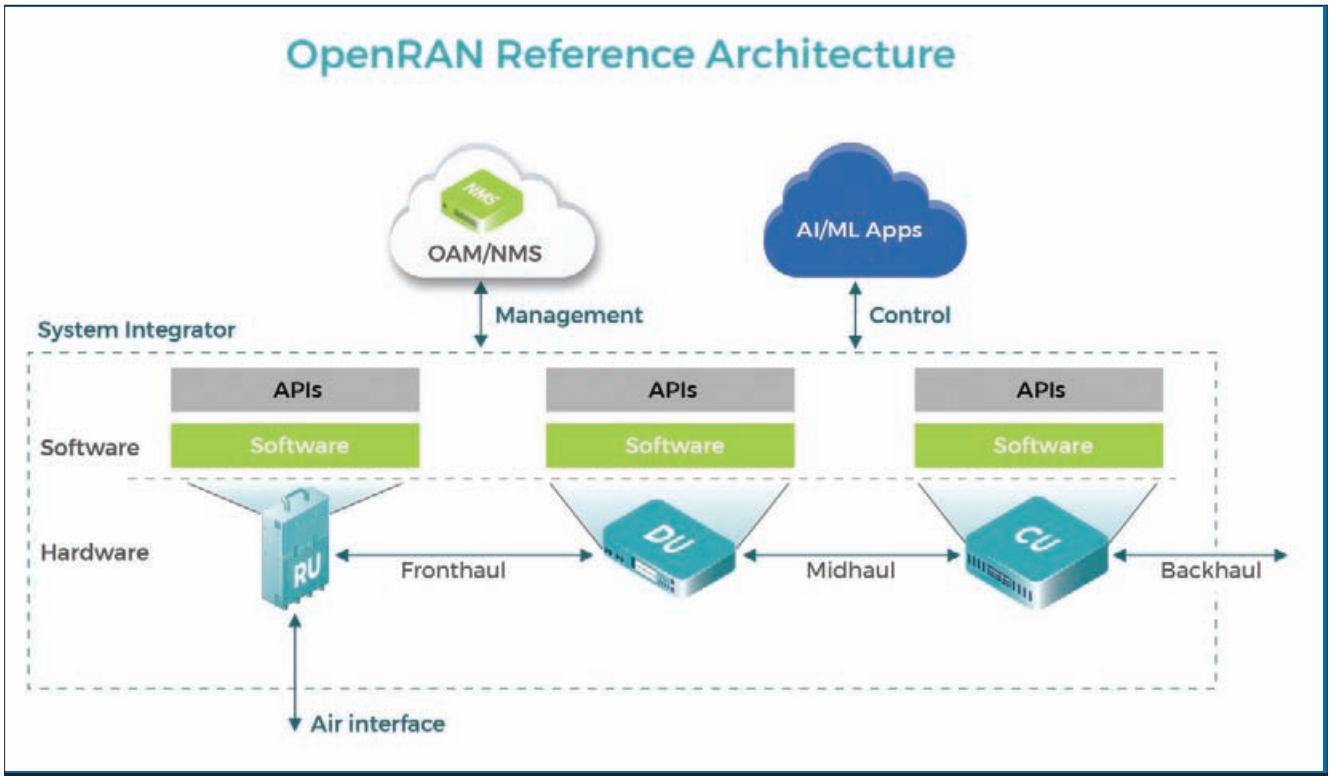

Figure 1. Courtesy of Telecom Infra Project, *https://telecominfraproject.com/openran/*

for some time, such as network function virtualization (NFV) and orchestration along with artificial intelligence and machine learning. However, this does not come without its own set of challenges, especially in handling real-time sensitive processing in the lowest layers of 5G radio baseband. One of the key challenges that will need to be overcome - despite Marc Andreessen making his famous claim a decade ago that "software is eating the world" - is a significant penalty is paid in terms of performance in wireless technology without proper hardware support.

5G is very complicated. However, the multi-standard technologies that most MNOs run are even more complicated and require immense computing power to manage Gigabits of traffic from thousands of users across hundreds of MHz of spectrum across various bands using multiple input/multiple output (MIMO) technologies. Hence the massive R&D budgets of Huawei, Ericsson and Nokia have allowed them to develop application-specific integrated circuits (ASICs) for their RAN processing needs that currently cannot be met cost efficiently with general purpose processor platforms or field programmable gate array (FPGA) based designs.

Even the big vendors are sometimes challenged by keeping up with demands. Quite famously, Nokia initially made the wrong bet on chip technology for their early 5G base station designs, resulting in the loss of big contracts in China; ultimately this played a part in a major management shakeup and redesign of the portfolio. Although Ericsson and Nokia (but not Huawei) are supporters of O-RAN, the Swedish vendor recently took a shot across the bow of the white box solution proponents claiming that its proprietary platform and ASICs are years ahead of any existing commercial off-the-shelf technology in terms of processing power for RAN specific tasks. They made the same analogy that Apple recently did with the launch of its M1 processor to replace Intel processors in Mac computers, that a very tight integration is indeed needed between software and hardware to get the most efficiency across all dimensions of a solution. This has been a poorly kept secret for some time and led to many calls from O-RAN members to the chipset industry to get behind their ambitions. We are starting to see some manufacturers now answering this call, although it will be some time until new chipsets specifically designed for Open RAN requirements will be generally available.

Other challenges are related to scale and the need for testing and integration. The MNO vendor community enjoys several orders of magnitude greater scale than the satellite industry does, but this is still only true for a select few. The barrier of entry for new RAN vendors is quite high, and it is difficult to scale to support the massive deployments MNOs are looking to do in 5G. When it comes to testing and integration, one of the advantages of a monolithic architecture is that it comes pre-integrated and tested. There are less dependencies on different vendors' software and hardware across the radio access network for which someone in an Open RAN deployment needs to take responsibility and ownership. Both O-RAN and TIP have rightfully identified the need for testing and validation and are making it a priority in their project groups to accelerate commercialization.

Despite Huawei not having joined the O-RAN Alliance, perhaps this will lead to some future, interesting IPR discussions as the Chinese vendor lay claim to a significant patent portfolio (important to note is that O-RAN does not equal open source but is based on the same FRAND principles as 3GPP). The support for the initiative is massive with Vodafone, Airtel, and AT&T, along with several other prominent MNOs behind it together with many well-known names in the infrastructure and chipset world like Ericsson, Nokia, Cisco, Dell, Intel, Nvidia, Qualcomm and ARM.

"Other challenges are related to scale and the need for testing and integration. The MNO vendor community enjoys several orders of magnitude greater scale than the satellite industry does, but this is still only true for a select few. The barrier of entry for new RAN vendors is quite high, and it is difficult to scale to support the massive deployments MNOs are looking to do in 5G."

While the Open RAN market currently generates just a few hundred million dollars in revenue, the forecast of expected growth varies greatly. Some predict it will be a several billion-dollar market very soon, while others take a more cautious approach. However, the growth in revenue is expected to be in the double digits year over year and a middle of the road assessment of the total market size put Open RAN at US$4-5 billion or about 10 percent of the total RAN market by 2025. While some of the technical, commercial and deployment challenges have been discussed above, most MNOs have made their first cut of 5G infrastructure vendors already and picked one or more of the existing RAN vendors as their partners for the first phase. As the 5G rollouts mature and the second wave begins in a couple of years, more opportunities for Open RAN will emerge.

Satellite industry benefits

So, what benefits can the satellite industry draw from this development, and what can we learn and apply to our industry and ways of working?

One question that consistently arises in satellite-focused webinars and industry events is: Why can't satellite communications be more like the mobile industry and rally around a standard, and enjoy the same economies of scale and ecosystem that they do?

I can see a few reasons and it applies a little differently depending on what sector of the satellite industry you look at. While the satellite industry the last couple of years has seen more investments in space-based technology than ever before, the size of investments is still small compared to the overall MNO industry. Money, innovation, and talent gravitate towards where the nice returns are, both personally and financially, and while the satellite industry is making great strides especially in the last few years, it still has some ways to go as an industry to enjoy similar benefits.

Secondly, key to the MNO industry's success, despite some being frustrated with both the process and speed of innovation, is 3GPP. This is the technical working group that for over 20 years has written the technical specifications that are the basis for the 2G, 3G, 4G and 5G standards. 3GPP provides the foundation that helps establish a market and an ecosystem that has both massive scale and stability over

time. Satellite technology used for telecommunication services in C-, Ku- and Ka-band, such as broadband access to enterprises and consumers and backhaul for MNOs, has less cross-industry cooperation. Judging by many of the new and proprietary NGSO constellations and V-HTS platforms in development, the industry has yet to agree on a standard that can potentially yield similar benefits. While some work is being done to leverage open standards and building practices in teleport infrastructure and how to connect to other telecom networks, little has been invested in standardizing satellite designs and air interfaces end to end to create a similar ecosystem to 3GPP. And many argue there are good reasons for it as satellite designs for high-speed broadband services are different than building a terrestrially based radio access network and include challenges that are truly unique to satellite communications.

Embracing 3GPP

Now, of course, there are always exceptions to any rule and what is inspiring to see is that several satellite companies particularly with interest in L and S-band are fully embracing 3GPP for predominantly narrow band access services from space. These are the use cases that looks at IoT, texting and voice services similar to what we are used to in terrestrially based cellular networks. These companies are set to leverage not only the massive user terminal chipset ecosystem from companies like MediaTek, but also well-defined BSS/OSS systems built for scale along with all the innovations coming from Open RAN and similar initiatives surrounding the entire mobile ecosystem. Disaggregated solutions will help add the flexibility and economies of scale these companies need to succeed with their satellite RAN.

In terms of the new base station designs and vendors that will emerge as a result of Open RAN, the satellite industry is poised to benefit from increased competition and eventually lower cost base station equipment. As anyone that has ever been involved in rural deployments of wireless technology knows, one of the key challenges is always about closing the business case and total cost of ownership. Many of the hardware and software vendors in the Open RAN community have a specific focus on connecting the unconnected with new and innovative solutions and the satellite industry is set to gain from this. The Telecom Infrastructure Project where Comtech EF Data is a member does a tremendous job at bringing companies together to collaborate cross-industry to solve the commercial and technical challenges of connecting the unconnected.

Many will argue that the best fit for the first generation of Open RAN is actually with rural and greenfield deployments as Open RAN will need some time to support high bandwidth multi-standard deployments and deal with difficult challenges like massive MIMO and interference cancellation that is more common in urban settings. As the GSM industry association (GSMA) point out in their analysis on how to reduce the digital divide and close the coverage gap, innovation needs to happen in two areas; network infrastructure including base stations, backhaul and energy, and innovation in business models including a service led approach through cloud enablement and collaborative deployment models. Connecting the unconnected has been at the core of what Comtech EF Data has been doing for years and we are happy to work and collaborate with satellite operators, mobile networks operators, infrastructure vendors and industry associations like TIP to make it happen.

As shown in Figure 1, the new functional splits that are being specified rely on a front-haul interface between RU and DU and a mid-haul interface between DU and CU. Front and mid-haul interfaces are very high-speed interfaces that requires low latency and delay variation making them a challenge even for LEO constellations. The opportunity for satellite backhaul still remains with the traditional backhaul interfaces, Abis, IuB, S1 and N3 that has for many years now been successfully backhauled over satellite to connect to the core network. An added benefit that comes with the new design philosophy is that introducing computing power closer

to the edge of the mobile network will allow for more traffic and services to stay local, making the business case for satellite even stronger as latency and bandwidth becomes less of an issue. A parallel, and interconnected development with Open RAN is happening that will leverage local or regional, private or public cloud infrastructure that distribute computing and storage capabilities far out in the networks in what is called EDGE computing. EDGE computing and the ability in 5G and Open RAN networks to provide service delivery closer to where it is actually consumed is in itself perhaps one of the most significant enhancements of mobile network infrastructure in a long time. Some envision that just like the APP/Play store helped bring new applications, services and companies to market leveraging the smartphone ecosystem (think Uber, TikTok, etc.), so will EDGE computing help bring new services, innovations and entrepreneurs inside 5G networks. This may one day help transform many businesses and value chains.

Usher in a new era

Industry 4.0 for instance will usher us in to a new era of industrial automation, machine learning and artificial intelligence, and 5G and distributed computing will help make it happen. You don't have to look far to also see several opportunities for a better satellite service delivery model happening at the EDGE. As an example, it has been a wish of the satellite industry for many years to leverage the inherent broadcast capabilities that come with GEO satellites also in radio access networks.

Finally, there is now a natural entry point in mobile networks for content delivery that fits well with satellite broadcast capabilities. Another possibility is that the local computing and storage capabilities may one day also lead to satellite modems as a service or as a cloud native or NFV application running next to RAN specific software.

While O-RAN in itself is not developing any new waveforms or mobile standards, it is working in a symbiotic relationship with 3GPP helping plug some of the holes in a few of the interfaces that has excluded competition and innovation from happening. And while 3GPP will continue to be the flag bearer of mobile standards and work within its well defined and rigid process of bringing specifications to market, O-RAN has proven that Internet speed of innovation can happen alongside it using ways of working that has made companies like AWS and Google what they are today.

Although building satellite networks is different than building radio access networks, there are discovery and insights that can move freely in between. The O-RAN alliance has shown that if supply is constrained, innovation is held back or competition is not sufficient, it is possible to challenge the status quo and make a change. One individual company would have difficulty making the necessary changes, but an alliance of companies coming together with a common vision can do it as proven by the few years O-RAN has been in existence. In the telecom world, a whole new ecosystem of hardware and software, applications and services are being developed that is open and inclusive and leverage the latest in Cloud technology, machine learning and artificial intelligence and apply an Internet age way of working and thinking to an existing technology and market.

As the satellite industry is moving towards a new era of NGSO, V-HTS and 5G supported satellite networks, we are at the cusp of a new space age that will propel our industry to the mainstream, and we will enjoy similar benefits. Comtech EF Data is embracing this transformation and look forward to working with our customers and partners to bring new innovations and solutions to market that will help make a lasting impact on society.

Global connectivity. Photo courtesy of Fotolia

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The key to leading in the modern space era

With the number of satellites headed for orbit sky rocketing, manufacturing costs are dropping by orders of magnitude reflecting new production techniques and processes. However, given the still-high overall expense of satellite operations, it is vital that standards remain sky high even within the move to economize.

Roman Buff, Vice President - Market Manager Aerospace, HUBER+SUHNER

Right now, companies are racing to provide a solution to the growing demand for connectivity, by sending masses of satellites into space. Over the next four years, there are expected to be over 38.6 billion connected IoT devices worldwide, which will all require a reliable connection. As consumer technology advances, everything from our phones to our fridges are connected to the Internet, and as far as industry is concerned, the popularity of industrial IoT is soaring, too. Satellites can provide connectivity all over the globe and are not restricted in the same ways that terrestrial networks can be.

As they are sent into space, these companies need to ensure their satellites are economically viable. While savings on infrastructure and operation are important, there is more to the equation than cost-cutting. In order to withstand the test of time, satellites must be robust and reliable, to continue offering the connectivity that is expected by consumers.

How many satellites are there, exactly?

The short answer is around 4,000 satellites as of April this year, with more being sent into orbit all the time. These are largely made up of GEO, MEO, and LEO satellites which all have their own unique features, making them suitable for varying connectivity needs. For example, GEO satellites can cover a huge area of the Earth's surface, due to their position high in orbit, but have high latency. LEO satellites on the other hand are required in a larger volume to cover a wide surface area, but are extremely close to Earth, and useful for applications which need a low latency signal connection. Innovative technologies like virtual reality and automated industrial equipment need this real-time connection to function, and so companies are in fierce competition to provide this.

The use of satellites is far more diverse than it used to be, when space was mainly occupied by government agencies and large telecommunications providers. Satellites were extremely expensive to produce, and send into orbit, meaning the aerospace landscape was much less diverse. Since production has become cheaper, many more companies are seizing the opportunity to send satellites into space and many more are being made. This causes a cyclical effect, in which even more companies are able to produce satellites, due to their economic viability. Although companies like SpaceX, OneWeb, Telesat and Amazon are leading the NewSpace race, smaller enterprises are following suit. We are beginning to see vast constellations of LEO satellites fill the skies, providing connectivity all across the globe, to a growing number of IoT devices.

SMP-SL Connector. Photo courtesy of HUBER+SUHNER

The evolution of satellite

While rockets are still needed to transport satellites into space, the cost of doing so remains high. As such, the manufacturing of satellite infrastructure itself has become significantly less expensive, enabling companies to increase their ROI. This is good news since the number of satellites needed for global high-speed Internet access is very high, posing a challenge to the NewSpace market. Satellites must be small, lightweight, and low-cost in order to remain economically viable.

While focusing on the financial implications of satellite manufacturing is important, the reliability and quality of satellite components should not be neglected. Companies cannot afford any errors, since repairs carried out in space are extremely difficult and more expensive in the long run. Investing more during manufacturing can save companies from costly malfunctions once the satellite has been launched. Those that will succeed in the modern space race are those that can strike a balance between low-cost manufacturing, and good quality infrastructure which will remain functional for years to come.

The race is on

Companies such as SpaceX and OneWeb have already started deploying satellites and have set ambitious targets for the coming years. OneWeb launched its first satellite in 2019 and has declared its goal to send over 600 into orbit. SpaceX is looking even further into the future, with ambitions

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to launch more than 12,000 satellites by 2027. The investment needed to manufacture and launch such a large number of satellites is significant, so costs must be kept as low as possible. This will be achieved by making savings during manufacturing, as well as ensuring a reliable, sturdy design that will be able to withstand the harsh conditions of space - excessive and unexpected repair work once deployed could be financially devastating.

These satellites require many high-performance components to build an infrastructure which effectively secures electrical and optical connections, able to withstand the aerospace environment for many years, and prevent costly repairs once in orbit. In previous years, push-on connectors for aerospace and space-flight applications had low endurance under severe environmental conditions, such as those in space. For example, the disengagement forces of a standard SMP (Sub-Miniature Push-On) connector previously prevented risk of connectivity loss, which would pose a significant risk to IoT devices on the ground.

Developments in leaps and bounds

Responding to this challenge, HUBER+SUHNER developed the SMP-SL (Sub-Miniature Push-On-Self-Lock) connector to include a low-profile self-lock feature. This design increased the robustness of the connection without increasing the small form factor of a standard SMP connector.

Thanks to recent innovations like this, and a large focus on the reliability of satellite components, pieces such as connectors have become much more reliable. Not only can they maintain a secure connection, but they are able to withstand the vibrations and shock levels during space flight. Without this, there is a danger that applications on the ground such as autonomous cars, healthcare IoT, or critical military applications could lose connection, resulting in consequences that put lives or sensitive information at risk.

Photo courtesy of HUBER+SUHNER ●●●

By implementing solutions which increase reliability, while also focusing on ease-of-installation and maintaining a small form factor, companies can be sure their satellite components will withstand the conditions of space. While minimizing costs is critical to ensuring the viability of satellite deployment, utilizing robust, hard-wearing components will ensure costs remain low throughout a satellite's lifetime. As constellations of LEO satellites fill our skies, this is how those competing in the modern space race will find themselves on top.

Photo courtesy of HUBER+SUHNER ●●●

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Satellite design for long life, high speed data management and connection

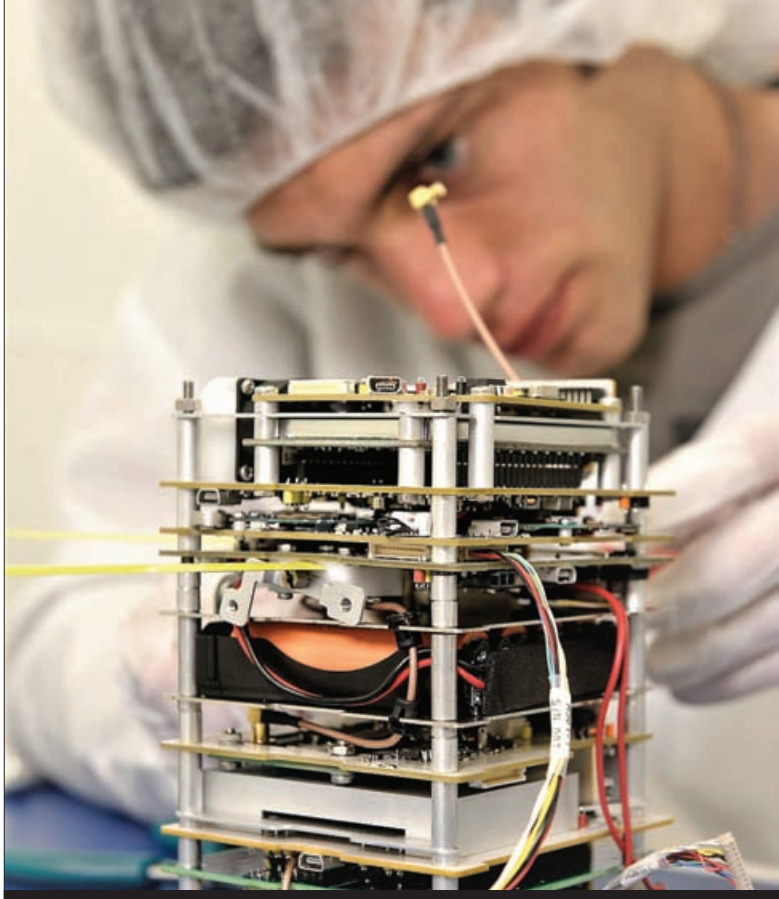
With the new wave of LEO and MEO satellite constellations coming into play later this year, demand for low power, lightweight, advanced circuit technology is on the rise. Space-based circuits must withstand extreme pressure and temperature conditions to remain functional in the depths of space, presenting new challenges for manufacturers.

Bob Stanton, Director of Technology, Omnetics

Squeezing more technical capability into each orbiting satellite has become critical in meeting the evolving demands on our satellite systems. The use of LEO based constellations has enhanced our ability to manage constant connection from all angles. This requires advanced circuits that communicate around the constellation chain while handling high speed digital data transmissions.

Since LEO satellites are close to Earth, the quality and speed of data transmission is significantly improved. In some cases, defense industries are also coupling surveillance and data services of both MEO and LEO altitude orbits with deep star trackers. This assists satellites to control their attitude to constantly focus on Earth's surface and improves precision point accuracy for ranging and position management. Additionally, constellations, like Iridium and Viasat's SATCOM networks, serve a massive array of position and communication demands that extend from commercial to mission critical defense technologies.

Omnetics Nano-ds on space computer



NASA Cubesat. Photo courtesy of NASA

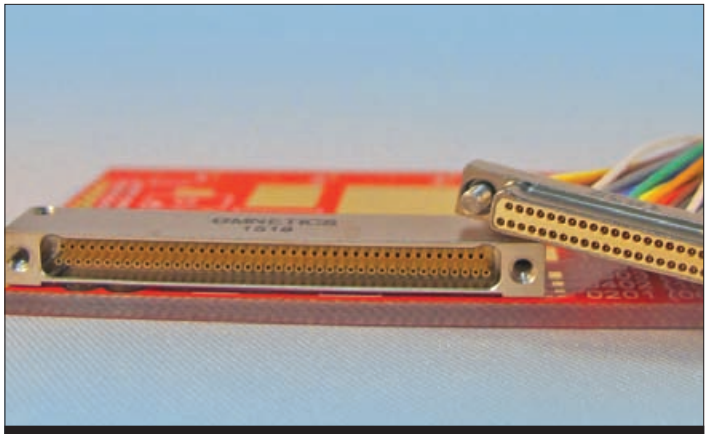
The current Defense Satellite Communications System (DSCS) is a US Space Force satellite constellation that provides military communications for globally distributed military programs. DARPA and other agencies are upgrading high speed digital signal modules to offer Protected Tactical Waveform methods. These will also contain protection from EMI and Anti-Jamming for soldier communications.

Beyond extending the capabilities and payloads of orbiting satellites, designers are also developing methods to keep them functional and updated while in orbit. Advanced programs, such as Space Logistics MEV-2, will add a key element in sustaining and upgrading our satellites while they remain in orbit, with visiting robotics.

Circuits with a difference

One result of the many circuit functions and improvements listed above is that satellite module designers are focused on high density, lightweight circuitry with increased capability. Fortunately, more recent chip technologies operate on very low current and power. More signal routing and interconnections are needed as capabilities are expanded. This includes routing signal, power, and sensor data from processing module to module while sustaining power to all sections of the satellite system. Much like the rest of the satellite, wire routing and connectors must also be simultaneously miniaturized and rugged. Wiring and connectors must be space qualified and offer a history of proven reliability for use in orbit or deeper space travel.

Omnetics Connector Corporation has years of experience offering space qualified, high-density satellite interconnections. Omnetics Nano-D connectors are built with NASA certified materials that exceed the specifications in MIL-DTL-32139 and are inspected per EEE-INST-002. The connector leads are set at .025", pitch, and are some of the smallest 'Space Grade' connectors on the market.



Omnetics 85 pin Nano-D connectors

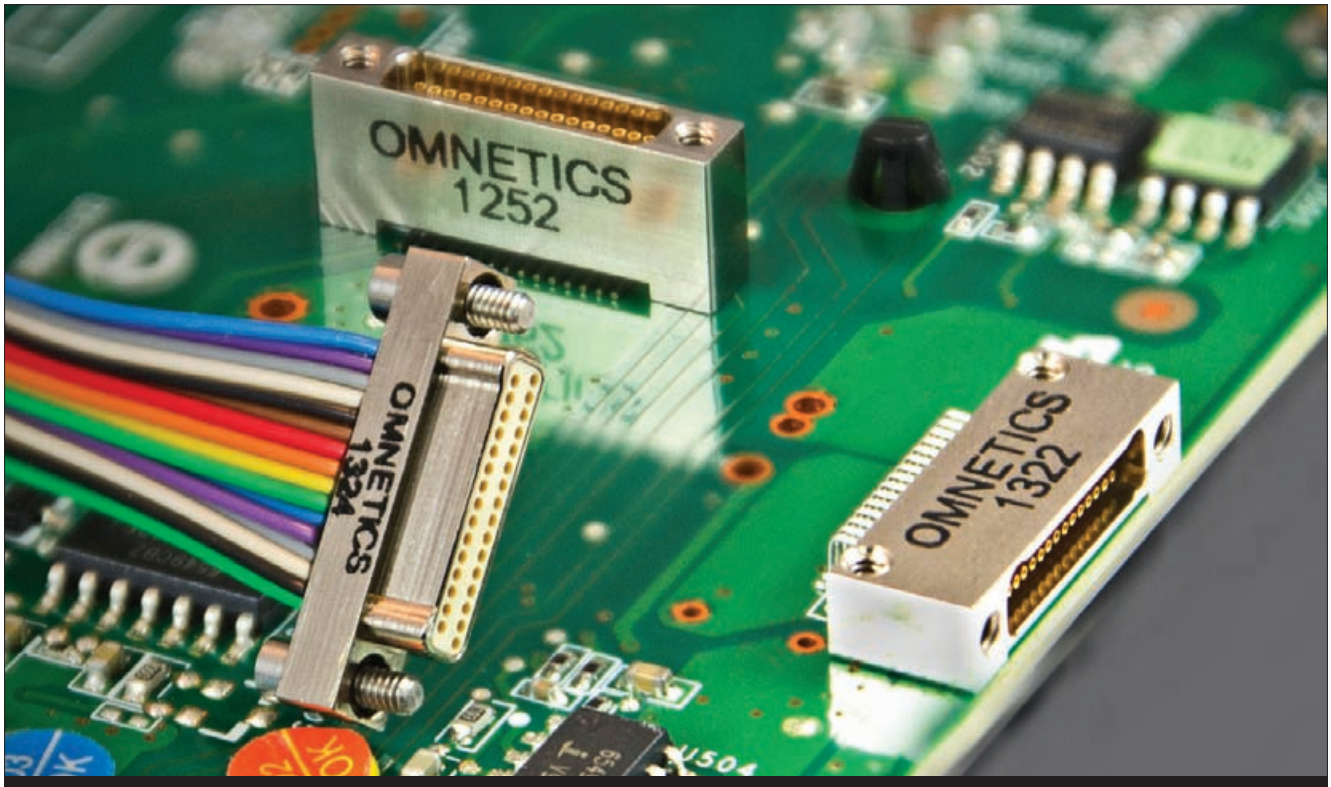
Compared to our larger Micro-D configurations, Omnetics has reduced size and weight by as much as four times that of standard Micro-D connectors and eight times that of previous D-Sub footprints. Like all of Omnetics connectors, these use our unique flex-pin gold-plated contacts that are polarized and shrouded by a unique liquid crystal polymer insulator, making the connectors ideal in high shock and vibration applications. Omnetics space grade connectors are available in several tail terminations. Standard pre-wired connectors come in 18" and 36" lengths with 80 micro inches of silver plated 30 AWG (7-38) PTFE insulated wire. Board mount options include both surface mount as well as thru hole, with flex circuit mounting also available.

The Omnetics space grade Nano-Ds are available in three shell materials. The standard is a Nickel-plated Aluminum with both Stainless Steel and Titanium available upon request. Omnetics chose these three material types as each shell finish is suitable for use in vacuum environments, whereas materials like Cadmium are prohibited for space. The Nano-D connectors come launch-ready and are designed to function in space travel. Since environments in orbital and deep space experience both heat and vacuum, the effects of material outgassing are critical for the circuits. In satellites, the gases can become a legitimate problem, contaminating chips, certain optical surfaces, and instruments. Omnetics space products meet and exceed NASA's well-established data and regulations for materials used in satellites and pass NASA specifications EEE-INST-002 that provides instruction on selecting, screening and qualifying parts for use on NASA GSFC space projects.

Omnetics' Nano-D connectors are readily available to meet all three levels of NASA device specifications. One standard procedure is to request a universal space standardized test method specified in ASTM E 595. Designers can also discuss details of each of three screening for; Level 1 for the highest level of reliability or for applications deemed 'mission critical,' Level 2 is for high reliability, and Level 3 is for standard reliability.

A connection revolution

High speed digital signal processing, new SOSA standards and others are increasing the demand for qualified light-weight connectors and cabling. Today's space applications fit perfectly with Nano-D connectors and can provide signal speed formats as needed. Wiring designs available include IEEE 1394 fire-wire cable and expands on to USB 3.1 formats and CAT-6a wiring and beyond. Cable shielding designs for noise-induced jitter and alien crosstalk are readily included. Cyber intrusion and signal isolation is well protected by using metal Nano-D connectors with special back-shells sealed to cable shielding at Omnetics.



Space Qual. Nano-D on PC boards

Reaching beyond the stars

Rogue Space Systems is an innovative NewSpace startup designing on-orbit solutions for satellites and spacecraft delivering automated innovations to LEO, GEO and beyond through their Orbot™ technology. At a burgeoning moment in the NewSpace era, their offerings span a remarkable set of emergent, lucrative business cases. Founder and CEO Jeromy Grimmett shares his thoughts about the company's latest work, and their outlook on key market debates.

Laurence Russell, Assistant Editor, Satellite Evolution Group

Question: Since the year 2,000, some 140 GEO satellites have experienced critical anomalies, 10 percent of which occur in the first 60 days of orbit. How much have losses like these handicapped the space industry?

Jeromy Grimmett: It's difficult to approximate the losses caused by satellite anomalies because most are never disclosed to the public. Based on our research, the average revenue generated by a commercial satellite in GEO is roughly US$150 million per year.

Losses extend beyond the physical satellite by inhibiting direct revenue generated through the services provided by that satellite. The failures and losses involving national security assets can be immeasurable.

A key capability Rogue is looking to demonstrate very soon will be our Laura Orbot for the inspection and observation of space assets. Being able to assess and even monitor the deployments of satellites in space can go a long way to preventing or even diagnosing failures that occur.

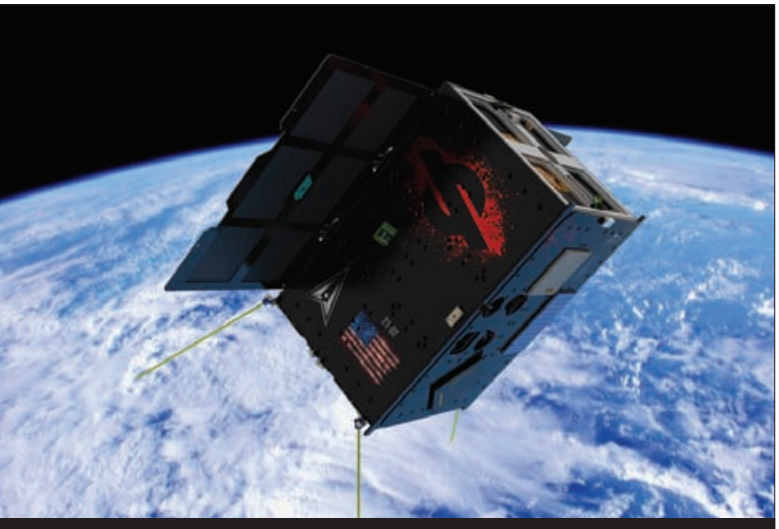


Photo courtesy Rogue Space Laura Orbot™ ●●●

Jeromy Grimmett, Founder & Chief Executive Officer, Rogue Space Systems Corporation ●●●

Question: This fragility doesn't stop at the commercial sector; government and military applications possess the same vulnerability. With space-capable missile stockpiles overflowing, what do we stand to lose with our intelligence networks at risk?

Jeromy Grimmett: A paper written by Capt. Michael Nayak, PhD, which advocated for the advanced research and capability development of SmallSat and CubeSat form factors, lays out the case in sobering detail as to the risks we face related to national security. He has written a few different articles on this topic. I agree with his contention that we should be using and advancing these form factors to decrease risks to US assets in the space domain.

We should also leverage those systems to serve as defense deterrents and active mitigation assets when threats are presented. What keeps me up at night is how easily an adversary can disrupt US space assets. Non-aligned international adversaries do not need anti-satellite missiles; they only need a swarm of well-developed 1U CubeSats placed in just the right spot to cause major damage to US satellites.

While LEO assets are vulnerable, GEO is at greater risk because small spacecraft are very difficult to detect with ground-based radar. To my knowledge there are no current defensive capabilities in LEO or GEO that would be able to protect these assets from a nefarious actor. The US intelligence community and military is heavily reliant upon our satellite fleet, not just for intelligence, but for guidance, navigation and communications. Losing these operational capabilities puts the US at great risk. Rogue is working to develop technologies and capabilities necessary to support our new US Space Force in their role to defend US interests in space.

Question: With both the existing level of debris and the increases experts have been predicting, how much more

challenging do you foresee SSA (space situational awareness) becoming?

Jeromy Grimmett: Space situational awareness and space debris will continue to be an issue with no complete solution anywhere near the horizon if the US government does not provide financial and political support. There are some SSA companies out there like LeoLabs and a few others that are developing ground-based radar networks to track debris at high-resolution and frequency.

Rogue is actively developing concepts for space based SSA. The challenges in this domain are going to continue to rise as mega-constellations propagate into LEO, and as launch costs are lowered which results in greater access to lower cost spacecraft from companies and governments that would not have previously had access to space because of the high costs involved. Today that is all changing and having a direct effect on the need for SSA.

Question: Rogue's Orbot™ unmanned in-orbit robotics are designed to perform inspection and monitoring tasks, as well as repositioning and servicing of satellites. Could you outline the technology for us?

Jeromy Grimmett: Rogue's Orbots™ are centered around an artificial intelligence system that aggregates real-time data to make decisions related to positioning and conduct of safe close-proximity operations. Rogue has focused on the key technologies such as the AI, compute, storage, and robotics that enable these small form-factor spacecrafts to perform these extraordinary operations.

The various classes of Orbots™ have multiple applications and uses in space, but they are all cut from the same technological cloth. We may scale up and down the size of the spacecraft all while using the same core proprietary technologies as the mission needs or dictates.

Question: This technology is obviously capable of mitigating satellite malfunction, but can it also address the existing problem of debris?

Jeromy Grimmett: Rogue's technology has been developed with space debris removal in mind. All of our development efforts have been aligned with providing space debris removal services as the market continues to mature. Our Orbots are designed to approach and assess a debris target so that it can be analyzed and ultimately deorbited or captured and returned to a depot on orbit for reuse or proper disposal.

There is no one single solution to removing space debris, so Rogue is attacking this problem with a multi-faceted approach utilizing a number of varied technologies to deal with the wide and varied range of sizes and masses of space debris that exists.

Question: Smart spacecraft like this are set to start appearing by mid-2022. What is required to ensure their successful development?

Jeromy Grimmett: When it comes to advanced technology in the domain of space, these efforts are capital intensive. Government and defense support of these efforts through SBIRs, contracts, OTAs, and of course private capital are all necessary to ensure these systems come to market in a timely manner. We are very fortunate that we have wide support and several efforts through the government and private funding that are underway to get the capital foundation Rogue and other space startups need to ensure the US continues to lead the world in developing space technologies.

Rogue is currently in a seed round and the feedback has been great. We are actively working with investors and open to new conversations with prospective partners. Recently, Rogue signed its first commercial partnership which is making great headway into the commercial space arena. Additionally, we expect our technology readiness levels (TRL) to increase from four to five by the end of this 2021 fiscal year.

Question: What's the future of orbital automation? Which applications will remain theoretical for now?

Jeromy Grimmett: A few years ago, we would have never imagined we could operate a helicopter on Mars, but on 18 February 2021, NASA made it a reality with the Ingenuity helicopter. Everything is theoretical until someone, or a group of capable visionaries, have the drive and imagination to bring it into reality. It may not happen immediately, but large space structures being built by automated systems are not far off.

Rogue Space Systems is one of the first companies to pursue the automated inspection of space assets. We believe our leadership in this capability will boost and support adjacent downstream commercial markets in the satellite servicing and space debris realm. I believe we are right at the very beginning of a surge of automation and robotic capabilities in space.

Within five years, we plan to successfully deliver payloads, supply missions, and support LEO outpost and space station construction. In ten years, we endeavour to build a deep space communication network to support asteroid mineral supply chain logistics, and outpost waypoint stations in space. In 20 years, we propose to extend outpost stations all throughout our solar system.

Photo courtesy Rogue Space Laura Orbot™

Unity 22 crew. Photo courtesy of Virgin Galactic ●●●

Space cowboys

2021 is, apparently, the ultimate year for space tourism, with Virgin Galactic and Blue Origin achieving huge world-firsts in commercial spaceflight activities, and SpaceX's next new space tourism venture right round the corner. Next year looks good for off-world firsts too, with full commercial roll out of Virgin Galactic and Blue Origin's spaceflight programmes for the masses.

Amy Saunders, Editor, Satellite Evolution

Space tourism has for hundreds of years been the dream of countless people across the globe. Instead of zipping off to another country – a thing we've stopped taking for granted given events of the last 18 months – mankind appears intent on zipping off to other planets.

Until last year, the only company which had successfully delivered space tourism services was Roscosmos, which in the 2000s delivered seven tourists to the ISS for some US$20-25 million per trip. However, commercial entities such as SpaceX, Virgin Galactic, Blue Origin, Boeing etc. have all been working tirelessly for decades to bring sustainable space tourism into reality. The market today is as positive as it has ever been for the future of commercial spaceflight.

ResearchAndMarkets' 'Space Tourism – Global Market Trajectory & Analytics' report has projected that the global market will grow at a CAGR of 15.2 percent from US$651 million to US$1.7 billion over 2020-2027, despite the ongoing coronavirus pandemic. The suborbital tourism segment, which includes most current players, is estimated to grow at a CAGR of 16.6 percent during the period to US$1.5 billion. Geographically, the US accounted for US$175.3 million in 2020, although China is expected to see the fastest growth, with a CAGR of 19.7 percent over 2020-2027. Japan (11 percent), Canada (13.2 percent) and Germany (11.9 percent) are also expected to see strong CAGR through 2027.

With the money flowing and interest piqued, 2021 has been the most dramatic year for space tourism history despite the ongoing COVID-19 pandemic, with fantastic achievements being reported across the board.

New horizons

July was a huge month for the history of commercial spaceflight, with both Virgin Galactic and Blue Origin achieving incredible first-ever crewed commercial spaceflights.

On 11 July, Virgin Galactic successfully launched into space from Spaceport America in New Mexico, with the company's first fully crewed commercial spaceflight. The carrier plane VMS Eve carried the SpaceShipTwo VSS Unity to 55 miles above Earth before releasing it, where it travelled further into space. The two pilots and four crew, which included owner Richard Branson himself as 'Astronaut 001,' experienced several minutes of weightlessness before descending safely back to Earth.

"Welcome to the dawn of a new space age," Richard Branson tweeted shortly after the flight.

Following the flight, a full complement of vehicle inspections and data will be reviewed, which will inform the next steps of the flight programme. The company plans two further test flights this year before commencing commercial service in 2022. According to Virgin Galactic, it already has more than 600 reserved seats at US$250,000 each.

Just a few days later on 20 July, Blue Origin successfully completed the first human spaceflight with four private citizens on board its New Shepard rocket. The crew included owner Jeff Bezos, his brother Mark Bezos, Wally Funk (the oldest person and woman at 82 years old to ever fly in space), and Oliver Daemen (the world's first commercial astronaut to purchase a ticket and fly to space, and the youngest person at 18 years old to ever fly in space).

The New Shepard rocket was launched from Texas; the crew capsule separated from the booster after around three minutes, just before reaching an altitude of 62 miles above the Earth, the internationally accepted boundary of space. The crew experienced around four minutes of weightlessness

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at a peak altitude of 66.5 miles, more than ten miles higher than the Virgin Galactic flight. The capsule and reusable rocket booster both re-landed safely on Earth following the journey.

"Today was a monumental day for Blue Origin and human spaceflight," said Bob Smith, CEO, Blue Origin. "I am so incredibly proud of Team Blue, their professionalism, and expertise in executing today's flight. This was a big step forward for us and is only the beginning."

Like Virgin Galactic, Blue Origin expects to fly two more crewed flights this year, with more planned for 2022.

Pipped to the post

Of course, both Virgin Galactic and Blue Origin were pipped to the post by SpaceX last year, when in May 2020, for the first time in history, NASA astronauts were launched to the ISS on board a commercial spacecraft.

The SpaceX Crew Dragon spacecraft was lifted into space on board the Falcon 9 rocket, safely delivering the astronauts to the ISS some 220 miles above the Earth as part of an end-to-end test flight to validate the SpaceX crew transportation system, including launch, in-orbit, docking and landing operations. Now that the Crew Dragon has been certified for NASA's Commercial Crew Programme, operational missions can include four crew members and more than 220lb of cargo per trip, and the crew capsule can remain in orbit for at least 210 days per mission.

"This is a dream come true for me and everyone at SpaceX," said SpaceX's Elon Musk. "It is the culmination of an incredible amount of work by the SpaceX team, by NASA and by a number of other partners in the process of making this happen. You can look at this as the results of a hundred thousand people roughly when you add up all the suppliers and everyone working incredibly hard to make this day happen."

Since this first historic trip to the ISS, SpaceX has since made several more 'astronaut taxi' service trips to and from the ISS.

Moving beyond NASA missions, SpaceX plans to send its first all-civilian crew into orbit in September on its Inspiration4 mission. According to SpaceX, the crew capsule will be launched on board the falcon 9 as the world's first all-commercial astronaut mission to orbit. The Inspiration4 crew will receive commercial astronaut training by SpaceX on the Falcon 9 launch vehicle and Dragon spacecraft, orbital mechanics, operating in microgravity, zero gravity, and other forms of stress testing. They will go through emergency preparedness training, spacesuit and spacecraft ingress and egress exercises, as well as partial and full mission simulations. The mission will last three days and see the crew orbit Earth every 90 minutes along a customized flight path, before re-entering the Earth's atmosphere for a soft water landing off the coast of Florida.

Interestingly, in a departure from the Virgin Galactic and Blue Origin launches, Inspiration4 is a privately chartered spaceflight funded by billionaire Jared Isaacman to support St. Jude Children's Research Hospital. Isaacman will fly on a SpaceX capsule with St. Jude physician's assistant and childhood bone cancer survivor Hayley Arcenaux, data engineer Chris Sembroski and geoscientist, science communicator and artist Sian Proctor.

The future of space tourism?

For some, the opportunity to visit space is once in a lifetime, a chance not to be missed. Certainly, casual discussions with a wide variety of contacts suggest that the majority would jump at the chance to enter space, even if only for a few minutes, should their budget allow. However, given the training, health stipulations and risks involved, should space tourism become more affordable, it's very possible that uptake would be lower than expected when faced with reality.

What is space tourism anyway? This seems to be another matter of contention, and one that Virgin Galactic, Blue Origin and SpaceX have different ideas about. While Virgin Galactic and Blue Origin are currently targeting and indeed reaching suborbital space, for several minutes anyway, SpaceX is offering access to full orbit, a very sizable difference. Certainly, for SpaceX, Virgin Galactic and Blue Origin, suborbital and orbital spaceflight is just the beginning in deeper space exploration and, indeed, tourism. How far the possibilities will extend within our lifetimes though, remains a topic for discussion.

One final interesting point to note out of these historic achievements is that while Richard Branson and Jeff Bezos were both extremely eager to be on the first commercial flights to space, Elon Musk has not yet taken the ride, despite beating both into space with his company, SpaceX, last year. Even SpaceX's planned all-civilian mission in September will not see Musk take flight; indeed, it's been reported that Musk would rather spend his time building Starship (destined for the Moon) than spare a few days to trial his own commercial spaceflight service.

Blue Origin crew capsule interior. Photo courtesy of Blue Origin

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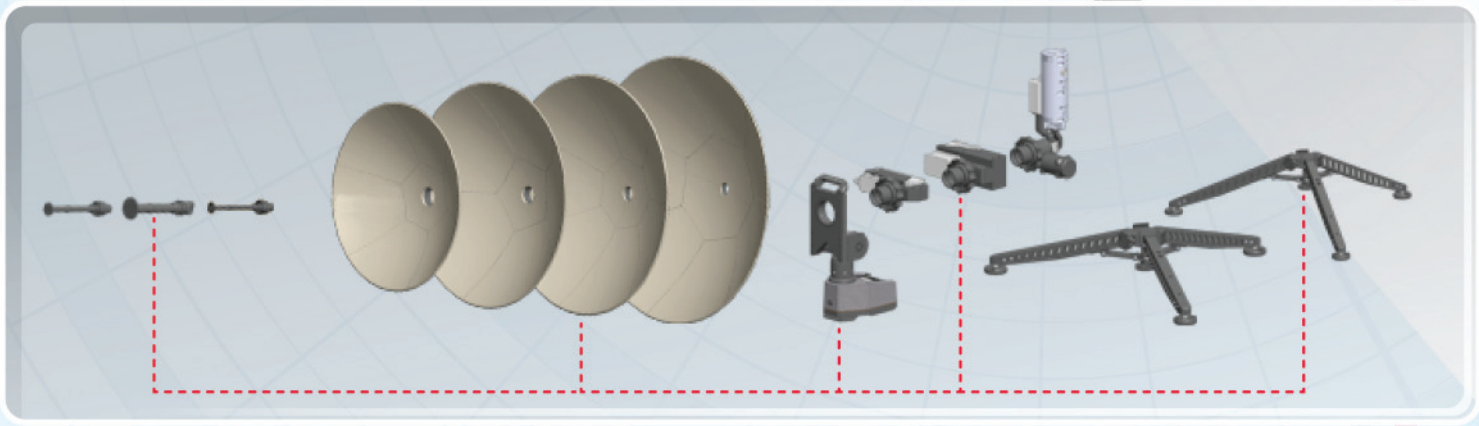

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