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SATELLITE EVOLUTION GLOBAL

October 2023

Front cover photo courtesy Orbit Fab

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Orbit Fab: Extending the life of assets in space

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- The demand for developing a satellite IoT business case
- Scaling the space Data-as-a-Service industry through AI-based automation
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Crispin Littlehales, Executive Editor

Perspective

In times of danger, anxiety, and sorrow many of us have looked up to the sky to regain a sense of connection and alter our perspective. The stars, the Moon, the rising of the Sun are often the harbingers of hope. So, what is it like looking down from above? Astronaut Nicole Mann, whom I met recently when she was in my hometown of Covelo being celebrated by the Round Valley Indian Tribes, gazed down upon us many times from her perch in the cupola of the International Space Station.

When asked during an interview while still in residence on the ISS, what wisdom her perspective inspired, she said, "I look at our beautiful planet and have this feeling of awe and amazement. You look out into the black emptiness of space and as your eyes move towards the planet, you pick up the atmosphere. It's this thin layer that's protecting our planet from the vacuum of space and it's the only thing that's keeping us alive. You don't see any boundaries. You don't see any divisions. You just see this little fragile planet in the blackness of space.

"I would ask people on a daily basis to think about the fact that you're a small part of this marble in space and how do you fit into this world? We are all on this planet together as human beings so how can we come together as that species and take care of each other and our planet? It's the only one we have."

There is a name for what astronauts and other people fortunate enough to travel to space feel: "the overview effect". When Jeff Bezos experienced it, he returned to Earth with a plan for reversing the environmental damage done by us polluting humans. "We need to take all heavy industry, all polluting industry, and move it into space," he proclaimed. By doing so, the Earth would have a chance to recover and thrive.

Is it even possible? A growing number of very smart people within our industry believe it might well be.

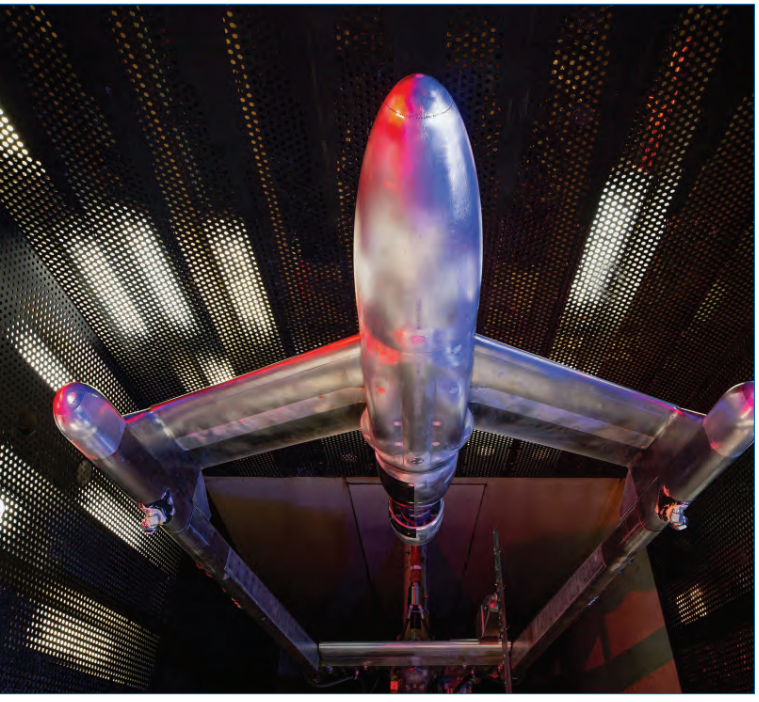

Photo courtesy WAAM3D

In this issue of Satellite Evolution Global, we interview Daniel Faber, the Founder and CEO of Orbit Fab. Faber predicts that in the not-too-distant future manufacturing in space will be a reality. He told us, "Over the next 50 years, industry will start to move into orbit to the point where we'll probably save the planet because instead of pumping greenhouse gases and burning oil on the ground, we'll move industry off Earth and that means taking 10 gigatons of carbon emissions off Earth. That's the future of humanity." I have my fingers crossed.

Guy de Carufel, Founder and CEO of Cognitive Space sheds light on how existing and additional downstream commercial verticals will grow their reliance on space-derived Earth observation data as a viable source of business development. Filomeno Martina, CEO and Co-founder of additive manufacturing firm, WAAM3D explains how Wire-arc additive manufacturing can play a significant role in helping satellite manufacturers optimize prototype production and deliver solutions more cost effectively. We also find out why Mission Microwave's block up converters (BUCs) are incorporated into so many antennas for Communications On-the-Move. Finally, Eric Menard, Vice President of Strategy and Business for Astrocast, shares his thoughts about why the time is ripe for systems integrators to build business cases for Satellite IoT.

Regulars

Features & Market Reports

Executive Q&As

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Thuraya and YahClick to partner with Gate for Technologies

MIDDLE EAST & NORTH AFRICA: Al Yah Satellite Communications Company has announced that its mobility arm, Thuraya Telecommunications Company, and its satellite broadband solutions provider, YahClick have signed a new service partnership to launch their mobility and data services in South Sudan in cooperation with the South Sudanese start-up Gate for Technologies (G4T).

Through this partnership, Thuraya and YahClick will provide several high-growth sectors in South Sudan with satellite-enabled connectivity solutions designed to serve specific requirements, constituting a significant step forward in the national efforts to re-build the Africa country.

The launch of Thuraya and YahClick's services took place in Juba, in the presence of Government officials from South Sudan, Thuraya's VP of Sales in the Middle East and Africa, Mr. Ammar Al Nuaimi and AVP for Africa region, Mr. Sami Hagana Ali.

The two companies' reliable, affordable, and easily accessible services and solutions have positioned them as the preferred mobile satellite communications provider in Africa. Yahsat has a longstanding commitment to the continent and its decision to launch Thuraya's mobility services in South Sudan will help to accelerate its growth, development and digital transformation in response to increasing demand for connectivity solutions.

Under the agreement, Thuraya's satellite technology will connect remote communities and support the government in its efforts to develop the nation's telecommunications infrastructure and enable e-government services. Yahsat will also collaborate with humanitarian agencies based in the country by providing them with the essential connectivity to support underserved areas.

Thuraya and YahClick partner with Gate for Technologies

Ali Al Hashemi, Group Chief Executive Officer of Yahsat, said: "Yahsat is proud to have a long and successful track record of nearly two decades in Africa, through our mobility arm, Thuraya and our broadband solutions provider, Yahclick. The new service partner agreement with Gate for Technologies reinforces our strong commitment to South Sudan and the African continent. As the country seeks to re-build critical sectors of the economy, consistent and reliable connectivity will increasingly play an integral role in furthering socio-economic development. We look forward to deepening our presence and expanding our offerings through this partnership with G4T. Together, we can leverage our combined expertise and in-depth understanding for the benefit of the South Sudanese economy."

Nhial Deng Nhial, Managing Director of Gate for Technologies said: "It is a great honour and privilege for us, and G4T in particular and the entire South Sudan, to sign the Service Partner Agreement with Thuraya, which marks the participation of a cutting-edge technology provider like Yahsat in the growth and development of the nascent South Sudanese telecoms sector. We are unlocking opportunities to fast track the digital transformation of the whole nation."

The new service agreement will leverage G4T market presence and partnerships with government entities, non-governmental organizations (NGOs), mobile network operators (MNOs), telemedicine, education and oil and gas sectors.

Fugro SpAARC's space operations set to grow with further funding from Western Australian Government

AUSTRALASIA: Fugro's Space Automation, AI and Robotics Control Complex (SpAARC) in Perth, Western Australia (WA), is to receive an additional AU$5 million in funding from the WA Government. Roger Cook, the WA Premier, made the announcement at the Pan Pacific Hotel in Perth on the morning of the opening of IPSEC 2023, Perth's Indo-Pacific Space and Earth Conference for leaders in space and cross-sector technologies.

This additional funding cements Fugro SpAARC's position as an international hub for space activities and will boost both WA's and Fugro's capacity for space mission operations. The funding will be used to help strengthen existing partnerships while also developing a local pipeline of experts who will contribute to SpAARC's world-class capabilities, ensuring Fugro is well positioned to support future space exploration.

The WA Premier Roger Cook said: "WA Government is seizing the opportunity to transform WA into a global hub for space and technology hub that attracts the best and

brightest talent, and accelerates the diversification of our economy. Leveraging WA's high-tech robotics and remote operations sector, Fugro SpAARC will capitalise on our significant space infrastructure and capabilities to position WA as the Southern Hemisphere's global hub for space operations and exploration."

SpAARC's Director, Fugro's Sam Forbes, said: "Space has always been a hotbed of innovation in robotics, automation and harsh-environment operations. This additional support significantly improves our ability to lead in this dynamic field, while also furthering the unique remote and autonomous capabilities we're working on at SpAARC and more widely within Fugro."

This exciting announcement follows Fugro's recently publicised involvement in the WA Government supported AROSE consortium for Stage 1 of the Trailblazer mission, delivered in partnership with the Australian Space Agency (ASA) and National Aeronautics and Space Administration (NASA).

Intellian and Inmarsat sign agreement for development of next generation Maritime Safety Terminal

ASIA: Intellian Technologies and Inmarsat Maritime have signed a Memorandum of Understanding (MOU) for the development of a next generation GMDSS safety terminal, designed for operation over Inmarsat's ELERA L-band network.

The new safety terminals will become the standard Inmarsat Maritime product for the next generation Fleet Safety service and will fulfil the requirements and performance standards of the International Maritime Organization (IMO), as part of a range of maritime SOLAS approved ship borne equipment including Global Maritime Distress and Safety System (GMDSS), Long-Range Identification and Tracking (LRIT) system and Ship Security Alert System (SSAS).

Intellian's GMDSS terminal will help to significantly enhance the safety of lives for the 1.9 million seafarers at sea around the world, and will be one the most technological advancements in safety services since the introduction of Inmarsat-C in 1991. The new safety terminal will allow a digital era of safety services to improve both preventative and reactive communications.

In addition to offering reliable access to Fleet Safety services, which includes an innovative Maritime Safety Information interface, the terminal features a Distress Chat function among its enhanced capabilities. This function automatically alerts the nearest Maritime Rescue Coordination Centre (MRCC) in case of an emergency on board, ensuring swift and coordinated response efforts. It also notifies nearby vessels, creating a network of support during critical situations.

Eric Sung, CEO of Intellian Technologies Inc.,said: "We're particularly proud of the development of this new GMDSS terminal and to have been entrusted by Inmarsat to develop this major innovation to their maritime safety

portfolio. It's a testament to our great partnership with Inmarsat, developing solutions that are innovative and reliable for customers all over the world. Our next-generation terminal that will vastly improve the safety of lives at sea for the 1.9 million seafarers and over 20 million passengers annually protected by the International Maritime Organization's policies. For our customers from shipyards to those going through a system upgrade, they'll be able to have a complete Intellian solution on board."

Peter Broadhurst, Senior Vice President Safety & Regulatory at Inmarsat Maritime, said: "Intellian has been a trusted partner of Inmarsat in advancing maritime communications, and we are excited to collaborate with them on the new Inmarsat Fleet Safety GMDSS terminal. This development represents a significant milestone in enhancing the safety of seafarers & passengers worldwide, and it underscores Inmarsat's commitment to providing innovative and reliable solutions for the maritime industry and protecting lives at sea."

National Football League teams up with SES for game content distribution

NORTH AMERICA: SES has announced a renewal of its partnership with the National Football League (NFL) to deliver NFL game content to over 35 broadcast partners across Europe, Asia, North and South America. Leveraging SES's advanced satellite, IP and fiber network, broadcasters can rely upon prime capacity with resilient back-up solution to ensure that viewers can enjoy NFL games uninterrupted, regardless of location.

In order to meet NFL's requirements, SES offered a unique combination of IP-based transport protocol (SRT) and its global satellite fleet to seamlessly deliver all game content. This included the addition of the recently launched content orchestration platform, SES SCORE, and SES's new ASTRA 1 Sports platform in Europe, with renewed prime satellite capacity for Americas (SES-14) and Asia to distribute over 150 upcoming games with the option to add more games in the future. SES has worked with the NFL since 2005, and today offers five simultaneous feeds for NFL games across its global content delivery network, with the ability to expand to 14 feeds if needed.

"We are delighted to continue our partnership with the NFL as they again put trust in our hybrid delivery model, utilizing our satellite network paired with extensive terrestrial infrastructure," said Michele Gosetti, Head of Sales, Sports & Events at SES. "Our track record with the NFL spans nearly 20 years, and as the league expands into more international markets, we have both the infrastructure and innovative video capabilities to meet their needs today and in the future."

"The NFL is committed to reaching more fans around the world through both live events and expanded broadcast engagements, including the NFL International Series, and making our games and content available in more countries via a growing ecosystem of broadcast technologies," said Jeffrey Lombardi, Senior Director, International Production Operations at the NFL. "Thanks to the strong hybrid delivery model SES offers us, we are

Photo courtesy SES

able to provide game content to more people and places around the world with the quality and reliability that ensures an enjoyable fan experience."

This project comes at a time when global interest in the NFL is increasing, with millions of fans spanning several countries around the world. SES has a long history of providing satellite-based sports content for the world's largest and most prestigious single-day and multi-day sporting events, broadcasting more than 700 hours of premium sports and live events each day.

US Department of Defense awards Low Earth Orbit IDIQ contract

NORTH AMERICA: SES Space & Defense has been awarded a five-year, Indefinite Delivery Indefinite Quantity (IDIQ) contract for proliferated Low Earth Orbit (pLEO) satellite-based services (SBS). The IDIQ vehicle was awarded through the Defense Information Systems Agency's (DISA) Defense Information Technology Contracting Organization (DITCO) by the US Space Force. Under the multi-award contract, valued at up to USD 900 million, the US Department of Defense (DoD), federal agencies, and international coalition partners can acquire fully managed low-latency LEO SBS from 16 selected awardees, including SES Space & Defense.

As the industry's leading COMSATCOM operator and integrator, SES Space & Defense possesses distinct advantages in providing the US DoD with value-added solutions at the tactical edge. The company leverages SES's global fleet of more than 70 Geostationary Earth Orbit (GEO) and Medium Earth Orbit (MEO) satellites, coupled with LEO partnerships, to create a fully managed and integrated terrestrial and space network.

Satellite services delivered via multiple orbits enable a comprehensive range of new connectivity capabilities for the US DoD. Non-geostationary satellite orbits (NGSO) - LEO and MEO - provide low-latency and flexible, fiber-like connectivity ideal for high-bandwidth, real-time applications, while GEO satellites enhance global resiliency and redundancy enabling a broader scope of government use cases. SES Space & Defense also offers enterprise management and control (EM&C) capabilities, facilitating a seamless, integrated network of COMSATCOM and MILSATCOM systems and extensive experience in building and operating global networks. This enables DoD users to enjoy resilient, redundant, and secure multi-orbit, multi-band network solutions.

"The pLEO IDIQ is the first multiple award contract to deliver pLEO COMSATCOM services to the government and military," said SES Space & Defense President and CEO, David Fields. "The contract structure is part of the US Space Force's new approach to acquiring SATCOM. These awards are foundational for COMSATCOM integration and proliferation into new waveforms and orbits enabling connectivity and communication at the tactical edge."

Photo courtesy Rich Schmitt Photography

Daniel Faber, Orbit Fab's Founder and CEO.

Satellite Evolution Global

Q&A

Orbit Fab: Extending the life of assets in space

We spend a great deal of money getting satellites into orbit only to disable and destroy them after a few short years. Once we can refuel them, the paradigm will shift dramatically. Not only will on orbit refueling reduce upfront capital, but it will also vastly improve utilization and extend the lifespan of the satellite. We interviewed Daniel Faber, Orbit Fab's Founder and CEO, to find out more about how his company will revolutionize the way we use our space-based assets.

Crispin Littlehales, Executive Editor, Satellite Evolution Group

Question: Gas stations in space…easy to say, very difficult to do. What inspired you to take on this massively complex endeavor?
Daniel Faber: When I was a first-year undergraduate student looking for something that would be beneficial to humanity, I decided that getting humans off Earth would address a bunch of existential risks and probably make for an interesting career. I wrote down a list of industries that might pay for the first permanent jobs in space—tourism, mining, and space-based solar power. I focused on all things relating to asteroid mining and that led me to an engineering degree; the building of a dozen satellites; and the wherewithal to create companies that could lead to permanent jobs in space.

For a few years I was the CEO at Deep Space Industries working on technologies that would eventually be strategic to asteroid mining. We bought a small thruster to move satellites around in orbit and then started building a line of thrusters. When the company was acquired by Bradford Space, I ran a bunch of different business models looking at what was interesting and talking to some of those customers we'd had for the space propulsion systems. I asked them, "What would it be worth if we had

Orbit Fab's RAFTI in-space fueling port will extend and revolutionize satellite missions

An Orbit Fab fuel shuttle is docking with an on-orbit satellite equipped with a RAFTI refueling port

extra fuel in orbit and how much extra revenue could you get from one kilogram of fuel?"

I was blown away when the answer came back: more than a million dollars of marginal revenue per kilogram of fuel. After hearing the same answer eight times in a row, I decided to drop everything else and concentrate on this difficult business problem. It's been five years since I founded Orbit Fab, and we've made some progress.

Consider this: everybody's in a paradigm right now of not having the ability to refuel and not being able to touch an asset once you get it into space or on the moon or on an asteroid. Think about what can happen if you can do repairs or maintenance. You can then start to treat satellites and other spacecraft like an asset that increases in value. At that point, the business models change. The financing models change. The operating models change.

Question: If you can protect and preserve these satellites, will there be fewer of them going up into space and will that have a positive effect on space debris?

Daniel Faber: It's hard to run a garbage collection service if you can't refuel the garbage truck. That said, I don't expect that on orbit refueling will mean fewer satellites. If you look at economics in history, when we make things more efficient and bring down the costs, people end up finding more utility.

We must use the new capabilities; make it safer and more reliable so when there is refueling, you can have the garbage truck service and clean up the debris. Even if you have thousands of assets in orbit, they can move out of the way and not worry about burning up their fuel. If satellites can't be removed, maybe there can be a recycling center and a junkyard in orbit. Again, the whole paradigm changes so we can make a safer environment whilst finding a thousand or a million times more utility by having more activity in space.

Question: In addition to the RAFTI fuel port, Orbit Fab has plans to create a whole refueling infrastructure. Can you describe all the pieces and how they will work?

Daniel Faber: In theory, it's very simple. Today, we are focused on getting fueling ports on satellites. We plan to work with suppliers who will manufacture fueling ports as drop-in replacements for the valves that satellites currently use. When our clients are equipped with the ports, the next step is to provide a vehicle in orbit that can deliver the fuel. That shuttle will have the guidance and navigation capabilities necessary to maneuver and it will also be able to dock to the ports and transfer the high-pressure fuel. Of course, the shuttles will run out of fuel, so we'll also have fuel depots which are relatively lower cost large tanks.

Question: What kinds of fuel will you be providing and how are you acquiring those?

Daniel Faber: While launch vehicles use cryogenic propellants, satellites require storable propellants that don't boil off or degrade. The most common of those is hydrazine, which is a mono propellant that you put on a catalyst and as it burns it decomposes. You can get decent fuel efficiency and a good high thrust. The second most common is xenon which is a noble gas. You put xenon through an electric propulsion system—effectively a particle accelerator—and you get much higher fuel efficiency but very low thrust.

Hydrazine is produced by chemical manufacturers and is not difficult to acquire. On the other hand, xenon is a trace composition of the atmosphere—one gram per 1000 tons of air—and is extremely rare. It gets produced on the back end of air liquification plants used by big industrial companies making gases and Orbit Fab has good relationships with those companies. As context, about 50 tons of xenon is produced every year and the space industry uses maybe 20 percent of that.

Question: The World Economic Forum has named Orbit Fab as a "Technology Pioneer". Are you in a league of your own or are there other companies that are in the space refueling business?

Daniel Faber: There are several space companies that the World Economic Forum has selected as tech pioneers. When it comes to refueling though, we are in a unique position. The industry need has been realized with the company's growth. Currently, I think we are the thought leaders in satellite refueling, but there are other people looking at what they might do as this is destined to be a competitive marketplace.

Question: What is Orbit Fab's timetable for the creation of a space-based refueling architecture, suite of delivery systems, and fuel options?

Daniel Faber: We are contracting with the US government to make the first delivery in 2025. We already have one fuel depot in orbit, and we did two tests for the interfaces and for pumping the fuel in zero gravity on the International Space Station (ISS). We are also the first private company to resupply the ISS with water. We did all that the first year that we were operating in 2018 and 2019. We worked very closely with NASA on what the requirements were and how to make everything safe. NASA said it would take two years to get through it, but we completed everything in four and a half months.

When we closed our seed round, we realized that we needed to fly our fueling port and use it on the ground at the launch site, which is the most dangerous time because there are people around and you're dealing with very highly energetic fluids. We went through the entire range of safety requirements and then flew our depot to orbit so that it would have flight heritage. That was a six-month development program. We are not afraid to progress quickly.

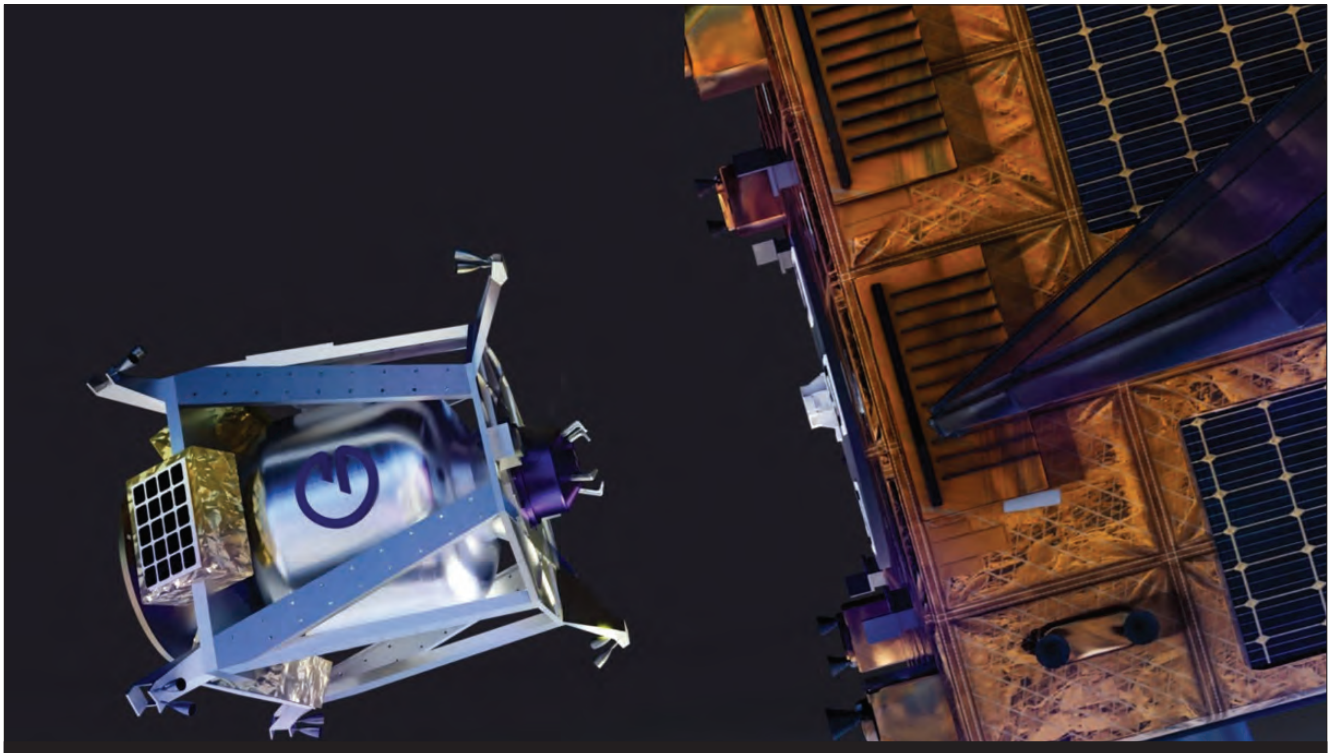
We haven't done much 3D printing yet. It's been easier to do the usual milling and machining. We build some of the fuel systems here in house and build the fueling ports as well. But we subcontract out for the spacecraft bus and the propulsion systems. We have a lot of suppliers who are experts in what they do. We tap that expertise and focus heavily on the refueling parts.

Our first contract was with NASA, the second was with the National Science Foundation, and the third was with the Air Force. Right now, our biggest contracts are with the Space Force. We are selling fuel to the US government through the Defense Innovation Unit. We have a small office in the UK as well and a contract with the UK space agency. Then, too, we have commercial customers so there is quite a range.

Question: What are your biggest technological and business challenges?

Daniel Faber: The biggest challenge, honestly, is the timing of the market. We are riding on the back of all the rendezvous and docking work that has been done by NASA and DARPA as well as other agencies. A lot of technology was already there when we formed the company. There were 7 or 8 companies that were working on the tow truck, garbage collection, tugs, or life extension where they attach and take over the thruster—those types of things. Now there are almost 200 companies.

The paradigm has changed. Everyone believes that



Refueling tanker equipped with a GRIP interface prepares to dock with spacecraft featuring the RAFTI in-space fueling port ●●●

satellite servicing is inevitable, and they can see the huge value that creates. When we started the company, we were asking investors to take a risk on that. Now we feel as if we nailed it in terms of timing, but I still worry about it. We need to spend a lot of capital upfront and then wait until people have the fueling ports and are ready to be refueled. Our business is all about closing that gap which is not trivial. The fueling ports must be very reliable, the docking system and the navigation has to be impeccable, and we must make certain that everything works and that we can justify the investments that are needed.

Question: How will Orbit Fab revolutionize the way spacecraft operate. What exactly is going to change?

Daniel Faber: Nobody knows for sure. It's like asking someone in 1985, "What is the internet going to do?" Back then, when the protocols had barely been created, no one knew about social networks or advertising potential or search engines. That's the situation where I liken it to what's going to happen in the space industry.

Look at the vacuum pump. Once it became accessible, you could take air out of a jar which sounds completely useless. What do you do with a jar with no air in it? The answer is all sorts of things—vacuum refrigeration, vacuum packaging, freeze drying, and many chemical processes that operate better when you have a vacuum unit with vacuum tubes. Vacuum technology eventually brought us to computers.

Now we have access to zero gravity. What do you do with that? Again, the answer is plenty—you can contain materials without touching the walls, you can remove buoyancy forces, you can mix materials that would never mix. The list goes on: you can create such a quiet environment that crystals will grow in interesting ways; materials can be combined and layered and do things that we've never thought of before.

Nobody knows what the limitations are because we have no experience but when that comes online, we'll see the potential unfold. It will be possible to manufacture enormous structures in space, because you won't have the limitation of gravity. You will be able to manufacture incredibly pure new materials and create things you can't make on Earth. Raw material feedstock will be sent back to Earth.

In time, more and more of the manufacturing processes will be done in space because if you need the first and tenth steps to be done in zero gravity, you'll do all the other steps there as well. Over the next 50 years, industry will start to move into orbit to the point where we'll probably save the planet because instead of pumping greenhouse gases and burning oil on the ground, we'll move industry off Earth and that means taking 10 gigatons of carbon emissions off Earth. That's the future of humanity.

All these pieces of infrastructure are fundamental to that end and fuel is one of the most critical pieces of the puzzle. The ability to inspect, repair, and upgrade satellites; the ability to gather trash, run a garbage collection service and do recycling; the ability to run a manufacturing service an then distribute to other places in orbit; the ability to get to an asteroid, get back, and get that material to a refinery and then elsewhere; and the ability to fly low at the top of the atmosphere where there's drag—all of these require thrusting and fuel.

From a national security perspective, you want to be able to appear and disappear without warning, to be mobile. Look at the history of conflict. Whoever has the best maneuverability wins. That's what we aim to enable with on orbit refueling.

Question: Looking out over the next 1 to 5 years and beyond, what do you see as the future trajectory for the company?

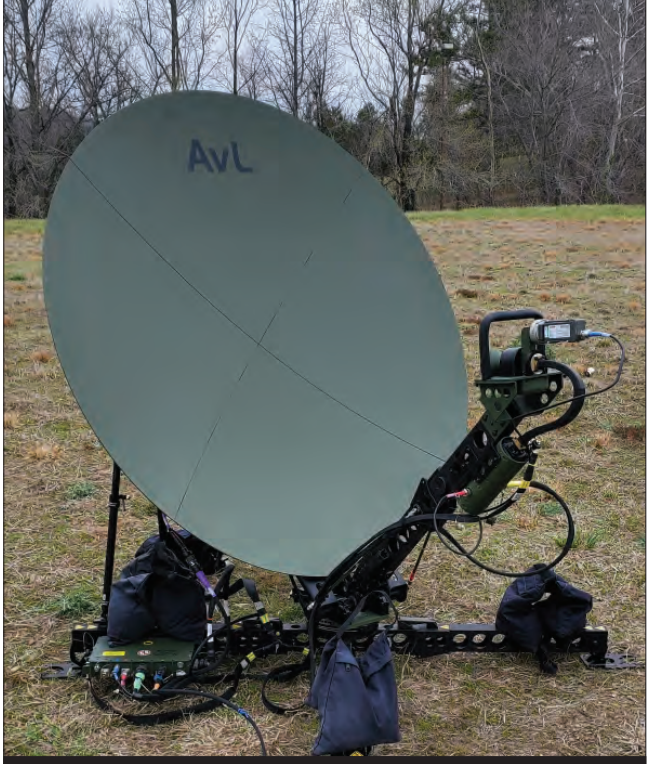
Daniel Faber: We are focused on selling the fueling ports, getting those widely adopted, and making sure they are reliable and function with all the propellants under the different pressures and temperatures. The second thing is to get the fuel shuttles flying along with the depots. In five years, I expect all that to be fully operational.

In ten years, I expect us to be heavily investing in building refineries in orbit. We can launch water and turn it into hydrogen or oxygen or even hydrogen peroxide. Once you throw in a hydrocarbon, you end up with a huge range of chemicals. We want to take material such as methane from the commercial space stations and recycle that for other chemical processes. So, the future of Orbit Fab is to be an industrial chemical supply company and to have the refineries in space.

Daniel Faber, Orbit Fab's Founder and CEO

Mission in motion

Mission Microwave Technologies was founded in 2014 with a single ambition: to create the next generation of Solid-State Power Amplifiers (SSPAs) and Block Up Converters (BUCs). The company manufactures a range of Gallium Nitride (GaN) based RF and microwave electronics for antennas built by leading players in the satellite industry for defense and commercial use. We spoke with Mission Microwave and several of their customers to pinpoint how and why Mission's unique cylindrical BUCs are enabling mission-critical applications.



AvL's 1.6m Tri-Band High Wind Manual Point Terminal ●●●

Crispin Littlehales, Executive Editor, Satellite Evolution Group

Who of us does not want to be informed? Whether the information we seek is mundane or life threatening, we want to know what is happening so that we can act accordingly. The more immediate and comprehensive the information is, the better. The challenge is how to collect and disseminate all that data into actionable insight as quickly as possible. Increasingly, we are turning to mobile and tactical satellite-based communications to achieve that goal.

According to research firm, MARKETS AND MARKETS, the Satellite Antenna Market is currently valued at approximately US$5.8 billion and is expected to reach US$10.5 billion by 2026. Market expansion has been driven largely by the deployment of low Earth orbit (LEO) satellites and constellations of satellites for communication. The increased demand for Ku-and Ka-band and Communication On The Move (COTM) solutions for platforms such as the expanding fleet of autonomous and connected vehicles for commercial and military use has contributed to industry growth. We are also seeing greater use of flat panel antennas (FPAs) and electronically steered phased antennas (ESPAs).

LIGHTWEIGHT AND POWER EFFICIENT

Antennas used for airborne, maritime, vehicular, and tactical applications as well as those antennas that support satellites in LEO and medium Earth orbit (MEO) require rapid and automated pointing and tracking. They must also optimize Size, Weight, and Power (SWaP).

Steve Richeson, Vice President of sales and marketing for Mission Microwave Technologies notes, "It is obviously easier to move and track a lightweight antenna system, and mobile applications have limited power and thermal budgets that demand efficient energy utilization. This is true regardless of the shape of the antenna; terminals using

The ThinAir® Ka1717 terminal from ThinKom delivers a market-leading combination of spectral efficiency, size, and drag for regional jets ●●●

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AvL's 2.4m X-Y Auto-Acquire MEO-GEO FlyAway Antenna

flat panels, parabolic antennas, and conformably shaped antennas all need to be efficient in terms of their SWaP footprint."

A portable or mobile satellite terminal consists of the following subsystems: the antenna/pointing mechanism, the baseband equipment, and the Radio Frequency (RF) components. These include the Block Up Converter and Power Amplifier (BUC) and Low Noise Block (LNB) Downconverter.

The BUC takes the signal from the modulator and boosts it from under a milliwatt to several watts or several hundreds of watts, thereby changing the frequency of a signal and making it a million times more powerful without distorting it.

Richeson explains, "LNBs do this with receive signals at very low power levels, but receivers in mobile terminals are largely unregulated because they really can't hurt anything else if they are poorly implemented. There are a lot of regulations on how to build a transmit terminal to avoid creating interference to the adjacent satellites or frequencies. Higher performing modems require better linearity to support higher order modulation signals schemes. Newer satellite bands, like the 30 GHz Ka-band, need higher frequencies and higher power levels to overcome rain fade."

ENABLING CUSTOMERS

Mission Microwave's product line has evolved around the needs of its customers who are, in turn, creating antennas and terminals to be used by people on the front line. That might be in the aftermath of a natural disaster, in an oil field, on an aircraft carrier, in the midst of battle, or in any other scenario where robust and dependable communications are critical.

"We try to provide the products and services to our customers that allow them to offer their end users a high-performance terminal that will survive many of the harsh environments in which they are used—all at a reasonable price," confirms Chris Callow, Director of Sales for Sat-Lite Technologies. Sat-Lite Technologies builds flyaway antennas, vehicle mount driveaway antennas, manpacks, and full motion LEO/MEO tracking antennas used in a variety of applications.

"We were an early adopter of Mission Microwave BUCs," adds Callow. "Their lightweight compact design fits in naturally with many of our smaller manpack and flyaway antennas. They are easy to integrate and don't take up much room for packaging in the transit case. Even their 400W Ku-band BUCs are small and light enough to mount on something as small as our 1.5m vehicle mounted antenna. In the past, it took a heavy custom oversized antenna baseplate to even consider mounting a redundant 400w system. It's amazing how Mission Microwave's products were able to change the game. What is more, they work…and they keep on working."

User feedback and responsive support are vital to product integration, particularly in a price-sensitive market. Richeson, who is himself an engineer, understands how important it is not only to be there when a customer has specific questions about one of his company's products, but also to provide as much information as possible about competitive products. "When someone is looking at our website, we make it very easy for that person to compare our BUCs with all the other ones in that same class that are available in the marketplace," says Richeson. "We've created a chart that compares all the data sheets from other manufacturers. Our customers are serious players who do their homework, and we want to facilitate comparison shopping. We exist to enable our customers to stay one step ahead by making antennas and terminals that are better than what's currently available. That means understanding the competitive environment on every level."

ON THE MOVE

When it comes to in-flight connectivity (IFC) reliability is key. It's expensive and time-consuming to replace systems so they need to go the distance and do the job as required. ThinKom, a leading supplier of airborne SATCOM antenna solutions, just passed 40 million operating hours with its systems; its antennas exhibiting greater than 100,000 hours mean time before failure (MTBF).

The company primarily supports the booming commercial aviation inflight connectivity segment, but also delivers systems for various government and military programs, typically for Intelligence, Surveillance, and Reconnaissance (ISR) applications. On the ground, ThinKom's ultra-low profile, network-agnostic, broadband RF antennas are used for high-speed internet back-haul, news gathering, border security, disaster recovery, and more. The company's newest innovations focus on space payload, gateway, and electronic warfare applications.

Denny Lynch, the company's Director of Business Development, works closely with commercial operations as well as various organizations within the US government

Sat-Lite mounted antenna on Viasat service truck

and the Department of Defense (DoD). His primary responsibility is to understand the unique SATCOM needs of end-users and help provide solutions that meet or exceed the requirements. Although ThinKom uses its own patented VICTS phased-array technology, it does not build high-performance amplifiers (HPAs). That's where Mission Microwave comes in. "We started working with Mission Microwave about five years ago, incorporating various BUCs into our ThinPack and ThinSat COTM terminals," Lynch recalls. "Most recently, Mission Microwave's lightweight 25 Watt Ka-band Stinger BUC was selected as part of the Ka1717 system that was developed for regional jet IFC. Production deliveries for a major US based carrier will commence next year."

WHEN THE GOING GETS ROUGH

There has been a dramatic shift in the way battlefield communications are conducted. Recognizing this, the US DoD has called for a comprehensive and collaborative Joint All-Domain Command and Control (JADC2) strategy. This concept to connect sensors and communications from all of the military services—Air Force, Army, Marine Corps, Navy, and Space Force—into a single network has as its goal to ensure that the joint force commander has "the capabilities needed to command the Joint Force across all warfighting domains and throughout the electromagnetic spectrum to deter, and, if necessary, defeat any adversary at any time and in any place around the globe."

This ambitious effort is by no means an easy task. According to a report published in September 2022 by the Center for Strategic and International Studies (CSIS), "The problem set features rapid technological change, the necessity of interoperability with existing systems and with new systems across the services, integration with allies and partners, new and non -traditional contractors, and novel acquisition approaches."

Mission Microwave's BUCs are integrated into a number of products that are currently part of the JADC2's communications strategy. Among those suppliers are AvL Technologies and L3 Harris Technologies.

AvL Technologies' core business addresses SATCOM, electronic warfare, and signal intelligence. All systems are networkable into JADC2 applications. Most AvL antennas go into remote, even unmanned, and harsh environments where reliability is paramount.

Dave Provencher, Vice President of New Business Development at AvL explains, "We are constantly advancing competitive new products capable of operating in LEO/MEO/GEO orbits at different frequency bands, and all while remaining lightweight and portable. Keeping up with new constellations requires advanced acquisition and

tracking techniques and drive systems with a wide range of antenna gains that can seamlessly transition between the LEOs, MEOs, and GEOs. AvL antennas are easily adaptable to different frequency bands, and uplink/downlink signal characteristics and waveforms thereby eliminating the need for the user to carry multiple antenna terminals. With the incorporation of GaN technology, small SWaP, high efficiency and standardized electrical and user interfaces, Mission Microwave BUCs are ideal for integration into AvL's multi-band, multi-orbit antenna terminals."

L3 Harris has delivered more than 10,000 deployable Very Small Aperture Terminals (VSATs) to the US DoD and its international partners over the last ten years. The majority of those systems shipped with commercial and unprotected modems, "But", notes Jerry Adams, the company's General Manager of SATCOM Programs, "the times are changing." The latest offerings from L3Harris include Panther II manpack and Hawkeye 4 Lite (H4L) flyaway. "As part of our development efforts, we are designing the next-generation Family of Terminals (FoT) for the Hawkeye 4 product line range in apertures from 1.3m to 2.35m axis-symmetric terminals designed around the integration of Mission Microwave solid state BUCs," he adds.

"End users leverage our terminals in multiple ways, ranging from short-term Special Operation Force (SoF) missions to long-term deployments where larger VSATs are used as remote HUBs. Each L3 Harris SATCOM product is easy to set up, tear down, and offers a common user interface platform, which makes them seamless to operate from terminal to terminal and sets them apart in the industry. Modem modularity and the ability to adjust to the mission are critical aspects of our equipment," Adams says.

BUILDING THE BEST

If you ask Steve Richeson why so many companies have elected to incorporate Mission Microwave's BUCs into their antennas and terminals, he's quick to say it's not because of the price, but, rather, a fear of being left out. "Our customers want to make a winning product," explains Richeson. "As people started adopting our product, they found that they could make terminals that were better than their competitors. If there's not a Mission Microwave BUC on that product, that manufacturer needs to be able to explain why."

Sat-Lite antenna on emergency vehicle in Japan

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The demand for developing a satellite IoT business case

Organizations around the world are recognizing the opportunities offered by sensor technology to improve operations. As a result, the operational IoT market is expanding. Systems integrators (SIs) must now build business cases for Satellite IoT (SatIoT) to reap the benefits.

Eric Menard, Vice President Strategy and Business, Astrocast

The environmental performance and productivity of remote copper mines and farmers' abilities to safeguard livestock and crops in a shifting climate are being transformed by weather monitoring stations that are connected to the internet. Cargo traceability is being enhanced within the shipping industry to lessen ongoing disturbances. Water quality across Africa is being monitored by charities to guarantee dependable access to safe drinking water is available to remote communities. The full potential of these IoT-led applications can only be realized by making use of a robust, proven, cost-effective satellite connection. Indeed, access to reliable, global satellite coverage is generating new opportunities for systems integrators (SIs) across the world, with estimates suggesting there will be tens of millions of SatIoT devices in use by 2023.

MARKET REQUIREMENTS

Even though satellite connectivity has been available for years—albeit it traditionally more costly—many of the key target IoT applications do not require the continuous or real-time communication associated with high-cost legacy satellite connectivity. These solutions play a critical role, but they are too expensive and power hungry to support a compelling business case for most operational IoT deployments.

A farmer requires only daily or twice daily updates of cattle location to track herd health. A copper mine uses intermittent updates on the water table level to provide operational visibility and meet environmental regulation. A shipping line does not require real-time updates of the temperature of its containers. It is perfectly adequate to transmit data either once or twice a day – or take multiple recordings which can be buffered and uploaded every 12 hours.

The value of this data is significant especially in areas such as shipping. The use of IoT sensors can ensure high-value cargo, including pharmaceuticals, are kept at the right temperature, and left untampered. Any deviation will prompt an alarm and allow remediation where possible, resulting in better integrity and reduced waste.

TRUSTED COLLABORATIVE PARTNERS DRIVE IOT CONFIDENCE

While the business case and potential are powerful, such IoT operations are incredibly cost sensitive. When a deployment may extend to tens of thousands, even hundreds of thousands of devices, small differences in performance and lifetime will fundamentally change the return on investment (ROI). The business case becomes even more sensitive when extended to remote areas without terrestrial network coverage, requiring satellite connectivity instead. How can the sensors be deployed to remote locations cost-effectively? What is the cost of satellite transmission? How long must the battery last on a sensor to ensure the ROI is not compromised? How can the data be collected and used to drive tangible commercial benefits?

SIs need robust due diligence to ensure confidence in the business credibility and model of the satellite provider, even before exploring the technology. Ensuring excellent satellite coverage, including across international waters, is essential. Business longevity is also fundamental for deployments that could be in the field for a decade.

Alongside this, it is also important to verify strong financial credentials. This means assessing the billing model, contractual arrangements, warranties, and support structure. Is the company committed to supporting its SIs not only in the prototyping and field-testing phase, but also through industrialization, production, and taking the solution to market? Each stage of this process will raise new challenges. The likelihood of commercial success will be transformed through having a partner in place with both the knowledge and commitment to overcome problems.

FUTURE PROOFING OF CONCEPTS

An SI should only make the investment in a SatIoT technology after a thorough assessment has taken place; one that confirms whether the foundations of the business case will yield the operational benefits that an end user (or the SI) requires. For many SIs looking to grow current IoT solutions, speed of integration is an important factor for consideration. From the quality of documentation to the availability of training, the way a satellite company works with its SIs to ease the integration of SatIoT into an existing IoT solution set can make a significant difference in time to market.

In recent years, a number of innovative SIs have been testing the latest generation of cost-effective SatIoT connectivity to understand the viability and requirements of an industrial scale deployment. They have built prototypes and invested in field testing. The process has highlighted the importance of ultra-low battery consumption to minimize the need for replacements in situ. Typically, a business case may only stand up if the battery lasts five to ten years. In some locations, the SatIoT solution

Eric Menard, Vice President Strategy and Business, Astrocast

can be integrated with a solar panel, overcoming the need for a dedicated battery.

Additionally, SIs have worked closely with SatIoT providers to optimize antenna design and ensure the antenna is reliable and easy to integrate. A small, flat antenna may be essential but additional questions will arise specific to an area of deployment. For instance, lightweight but robust enclosures are now used to securely attach an antenna to livestock to track their movement across remote farmland and identify any that leave the herd, indicating ill health or injury. Additionally, during optimization, an excellent supporting solution to achieve indoor satellite IoT deployments in rural locations with no terrestrial networks is through the simple use of a Bluetooth connection between the device and the SatIoT antenna.

Future proofing investments as much as possible is also key. Therefore, making bidirectional connectivity available is important as well. Updates can be downloaded remotely to the sensors as required—for example, when a customer wants to change the frequency of data recording.

CONCLUSION

Through discovering how to optimize SatIoT solutions and antenna design to deliver a robust, viable and cost-effective deployment, these innovators have led the way and, significantly, these organizations have proven the business case for SatIoT. While the demand for IoT has never been in question, it is now being better enabled through the cost-effective technology and connectivity available on the market.

This means commercial SatIoT advancements are now transitioning into the next stage of industrial scale deployment, whether it is within agriculture, shipping containers, animal tracking, or environmental monitoring, the sky is the limit.

Further, this is only the beginning. For example, an array of complex operational challenges exists within the shipping industry in its management and tracking of around 50 million containers across the world. Financial benefits here are being derived through monitoring temperature and tracking location, among other things. The war on drugs and piracy will be aided by the ability to determine if a container has been entered or tampered with during the voyage. Introducing smoke detectors will sound the alarm when a fire breaks out on board – a rising concern if owners fail to make the shipping company aware that a container carries potentially self-combusting cargo, like Lithium-Ion batteries.

Now, more than ever, the window of opportunity is wide open for SIs to utilize the expertise acquired in recent years to further investigate the reach and potential for cost-effective satellite connections across the world. By developing convincing business cases for SatIoT solutions SIs will be able to change and improve operational efficiency for companies of any size globally.

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Scaling the space Data-as-a-Service industry through AI-based automation

The remote sensing industry is expected to double over the next five years from about US$6 billion today to over US$11 billion by 2031. Deloitte recently identified Space Data-as-a-Service (DaaS) as the biggest key driver of growth for companies in the space value chain. Existing and additional downstream commercial verticals will grow their reliance on space-derived Earth observation (EO) data as a viable source of business intelligence. However, there still remains significant barriers to acquiring current and near-real time space-derived EO information.

Guy de Carufel, Founder and CEO of Cognitive Space

The operational and business processes that launched the space-based remote sensing industry do not scale to meet today's business speed and reliability requirements. Legacy issues that create friction for new and existing users include a lack of reliable remote sensing capacity; the inability of the remote sensing satellite operators to provide accurate commercial delivery times; and the complexity of the product pricing and contracting processes.

There is significant development happening to address these friction points: more streamlined acquisitions from the US Government, growth in launch and manufacturing capabilities, and advancements in the value chain—including the use of AI in automation of large scale constellation operations to extract useful information from imagery using computer vision.

A PERFECT STORM FOR GROWTH

Space has never been more accessible than it is today. The cost to launch satellites to low-Earth orbits have plummeted, dropping by 95 percent over the last ten years. Additionally, the time it takes to get onto a launch manifest has shrunk to under one year, which was unheard of a decade ago.

This, along with the commoditizing of components; the maturation and acceleration of satellite manufacturing and assembly; and the ability to readily make use of data from these satellites through AI-driven analytics leads to new venture-backed satellite operators and new constellations from existing operators. Deloitte identified five main segments which are expected to drive growth in the space market over the next three years: satellite integration, components, launch vehicles, value-added services, and payloads.

Guy de Carufel, Founder and CEO of Cognitive Space

US$280 billion has been invested in the space industry since 2013. Almost all of those investments were in the satellite and launch sectors, accounting for US$275 billion. These investments fueled the 320 satellite constellations currently at various stages of development and deployment which are expected to result in tens of thousands of satellites to be launched and operated in the coming years.

Space Data-as-a-Service (DaaS), sometimes referred to as Space-as-a-Service, has been identified as the primary driver for growth in the full space value chain with defense and intelligence agencies especially keen on purchasing space data for national security to maintain intelligence superiority against adversaries. Another important market driver is the new space race to build an ecosystem on the moon, a market projected to be worth over US$100 billion. Also taking shape is a cis-lunar infrastructure market where new very long-range communication, Positioning-Navigation and Timing (PNT), Space Situational Awareness (SSA), lunar surface-to-orbit services, and potentially in-space refueling capabilities will be required.

THE SHORTCOMINGS OF CONVENTIONAL METHODS IN THE FACE OF GROWING MISSION COMPLEXITY

As the number of satellites and demand for data continue to grow rapidly, the complexity in the management of these assets will increase exponentially – resulting in operational needs that will soon be unsustainable for human operators to manage effectively.

Complexity in operations arises from the need to schedule payloads to fulfill orders with various priorities, while considering the bottleneck of data downlink over a network of ground stations operated by various organizations. In the case of remote sensing, defense and intelligence customers are demanding that orders be filled

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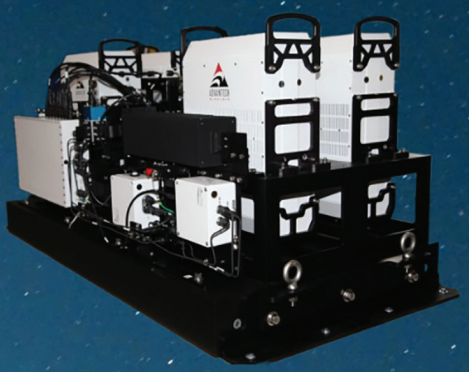

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in hours or even minutes as opposed to days or weeks, which adds to the mission operators' cognitive burden and impacts the fleet operator's ability to support more commercial customers.

There are several other factors that complicate the operation of satellites. For example, remote sensing satellites must contend with changing cloud cover and seasonal variability along with variability in priority and timing requirements from end-customers.

Only through automation will the data capacity from space be equivalently unlocked and accessed by the market at large, resulting in applications we can't predict today.

A significant new development in the space industry is the introduction of mesh networks in space with inter-satellite communications. This will enable constant communication access to satellites whether to command or downlink data at any time, stressing the need for dynamic automation. Finally, as the number of satellites in various orbits keep increasing, the danger of collisions and the need for automated collision avoidance amplifies the need for automation in operations.

AI'S JOURNEY FROM ATARI TO DYNAMIC SATELLITE FLEET MANAGEMENT

While ChatGPT and generative AI are now all the rage, decision making AI has been progressing steadily since the 1990's. AI is now capable of performing complex decision making in dynamic and uncertain environments, such as in dynamic satellite fleet management.

Several legacy players in the satellite industry still employ armies of operators for a small group of spacecraft—a process that scales poorly. Some of the newer operators of large constellations of satellites have invested several years to develop automated satellite operations, generally relying on logic based empirical software tailored for each spacecraft to achieve what is called "lights-out automation". Using classical logic-based software (if/then) can work and scale for homogeneous constellations but requires significant customization for each payload and satellite variant when constellations are heterogeneous and can be brittle against unusual and dynamic conditions.

Instead, the use of AI techniques as mentioned above can enable software for fleet management to be driven by data as opposed to hard coded logic. Through the use of neural networks, agents representing satellites can be trained against variable objectives, payload type and performance, and business logic constraints. The business objective can easily be adjusted from maximizing coverage to minimizing latency, while adapting to changes in the satellite's performance as it ages. It can also account for other satellites in the constellation to share the load, all without having to change a line of code. The space environment, use cases, and capabilities being deployed are changing too rapidly to hard code an automation strategy.

CONCLUSION

The constantly increasing cadre of companies that are currently deploying satellites with unique capabilities are now very much aware of the need to automate operations to stay relevant and competitive in the years ahead. Fleets of tens or hundreds of satellites will need to be completely automated against changing order requirements, environmental conditions, and dynamically changing availability of both space assets and data routing options.

Luckily, advancements in AI now make it possible to fully automate the operations of satellites and meet the growing demand for Space Data-as-a-Service and the associated expectations for shorter latencies and greater coverage. Satellites must become the autonomous drones of space, driven purely through machine intelligence, to satisfy the dynamic needs of the evolving market.

The remote sensing industry is set to double by 2031, driven by Space Data-as-a-Service, but faces barriers like capacity, accuracy, and pricing complexity

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Prototype flexibility using additive manufacturing

Complex supply chains, engineering workforce labor shortages, and evolving expectations around sustainability are some of the many challenges that the satellite industry faces today. Wire-arc additive manufacturing can play a significant role in helping satellite manufacturers optimize prototype production and deliver solutions more cost effectively.

Filomeno Martina, CEO and Co-founder of WAAM3D

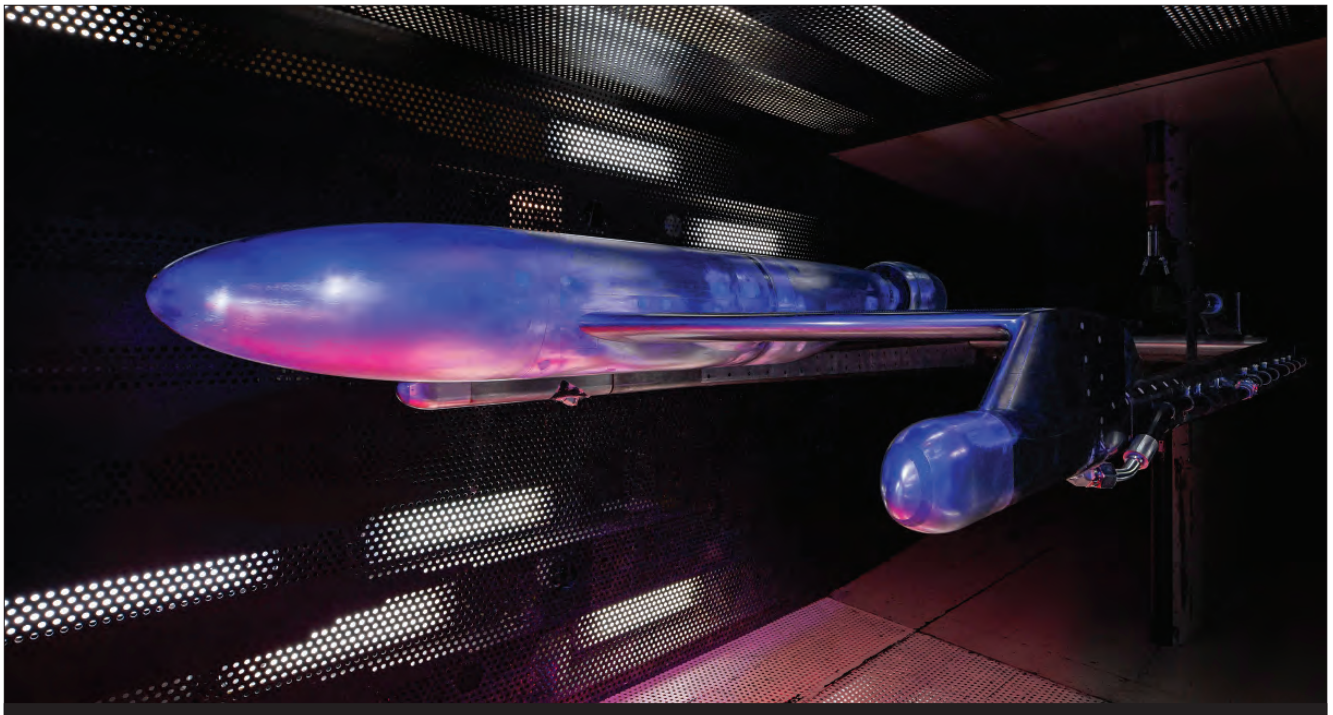
Additive manufacturing (AM) is coming of age, thanks to its multiple cost and material efficiencies. It uses significantly less material than other forms of product creation, such as subtractive processes, and can reduce the timeline from prototyping to production. It is no wonder therefore that the global 3D metal printing market grew to US$380.3 million by 2020 and is expected to expand at a staggering CAGR of 25.7 percent between 2021 and 2028[1].

Filomeno Martina, CEO and Co-founder of WAAM3D

FOUR AM PROCESSES FOR SATELLITE PROTOTYPES

When it comes to 3D metal printing, there are four AM processes that are particularly appropriate for satellite prototype applications. These are Laser Powder Bed Fusion (LPBF), Electron Beam Powder Bed Fusion (EBPBF), Wire Arc Additive Manufacturing (WAAM®) and Laser Metal Deposition (LMD).

According to a literature review of the four processes used in the aerospace industry that assessed their different technical parameters[2] (see table), WAAM is the most process efficient at approximately 70 percent (Riios et al. 2018), compared to EBPBF at 15 percent – 20 percent (D.



Aluminium wind tunnel model featuring a nose cone produced by WAAM3D for the UK's Aircraft Research Association, demonstrating that prototypes can be developed quickly and to defined tolerances using DED-Arc

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Ding et al. 2015b), and LPBF and LMD at 2 percent – 5 percent (D. Ding et al. 2015b). Its build rate for Titanium is also quicker too at 0.5 – 4 Kg/h (Williams 2016b), compared to LPBF at 0.1 – 0.18 (Bhavar et al. 2014), EBPBF at 0.26 – 0.36 (Dutta & Froes 2017) and LMD at 0.1 – 1.41 (Dutta & Froes 2017). However, despite layer thickness being thicker than the other processes (1000 – 2000 ìm), WAAM's surface roughness compared to LPBF, EBPBF and LMD makes it more suited for medium to larger scale components that have less complex geometry. When it comes to maximum build volume, WAAM is potentially unlimited (Williams 2016b), with EBPBF limited to 200mm x 200mm x 180mm (Bhavar et al. 2014), LPBF to 500mm x 350mm x 300mm (Bhavar et al. 2014) and LMD to 900mm x 1500mm x 900mm (Frazier 2014).

When deciding on which AM process to pursue for a prototype, the following needs to be considered:

- What is the minimum required feature size in the component? Due to layer height and melt pool width dynamics, the starting point for the prototype development process selection must be the minimum required feature size of the component.

First WAAM full-scale prototype of a titanium pressure vessel to be used in future manned missions for space exploration ●●●

- What surface finish will the end component require? The natural shape of the weld pool during the build process leads to a scalloped outside surface. The size of these scallops will depend on the bead height laid down. The surface of the metal prototype - and future components created - might need finishing if specific smooth or polished surfaces are required.

All AM processes follow the same procedure for creating a prototype. There is the translation of a 3D model—usually a 3D computer aided design (CAD) file—into a series of layers. These digital CAD designs can be easily altered between prototypes and the dissemination of the final design to other parties is straightforward. Following this, the bead dimensions of the deposited material, the slicing routines and the AM process capability are critical in determining how complex the finished prototype can be. Also, only a few AM processes offer the potential to produce fully dense metal components (Murr et al. 2013; Uriondo et al. 2015; Sun et al. 2013) with similar mechanical properties as traditional methods; thus, being suitable for aerospace applications (Joshi & Sheikh 2015; Uriondo et al. 2015)[3].

WAAM FOR LARGER PROTOTYPES

There is inevitably a trade-off in AM processes between surface finish and component size. For complex designs with thin walls LPBF is ideal, as it relies finer particles and laser spot sizes. For the production of medium to large scale components, such as cruciform, stiffened panels, wing ribs and flanges, impellers, tanks, etc. WAAM is ideal. This is because it avoids the expensive waste associated with machining materials such as titanium and can create less complex structures in a range of materials (from titanium, aluminium, refractory metals, steel, bronze and copper to Invar, nickel superalloys and magnesium).

WAAM PROTOTYPE – A TITANIUM PRESSURE VESSEL FOR SPACE EXPLORATION

A team comprising of Thales Alenia Space, WAAM3D,

First WAAM full-scale prototype of a titanium pressure vessel to be used in future manned missions for space exploration ●●●

Cranfield University and Glenalmond Technologies has successfully produced a first full-scale prototype of a titanium pressure vessel to be used in future manned missions for space exploration. The vessel is approximately 1 metre in height and 8.5 kg in mass. Made of the titanium alloy Ti-6Al-4V, it has been deposited using the WAAM process.

Due to the fact it is possible to go straight from digital drawings to final structures using WAAM, two individual pieces have been integrated into a single part, lead times have been reduced and the component has used 30 times less raw material than if it was created via traditional processes. By using the WAAM process, more than 200 kg of Ti-6Al-4V has been saved for each item.

Thanks to WAAM, prototype development can now be done in a matter of weeks. With so many pressures on satellite engineering at this current time, it's no wonder that WAAM is proving so popular with satellite manufacturers.

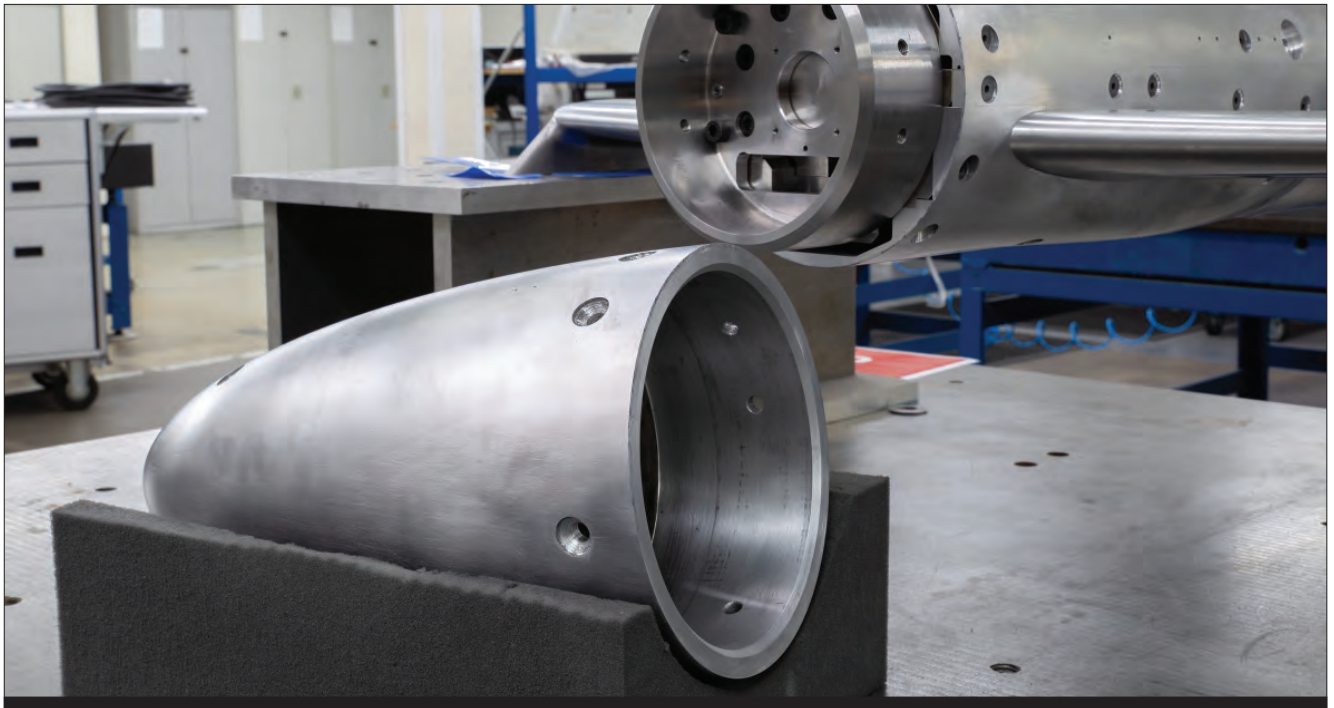
Parameter	LPBF	EBPBF	LMD	WAAM
Energy (W)	100 - 1000 (Bhavar et al. 2014)	~ 3500 (Baumers et al. 2016)	~500 - 3000 (Cao & Gu 2015)	2000-4000 (D. Ding et al. 2015b)
Overall Process Efficiency[2]	2% – 5% (D. Ding et al. 2015b)	15% – 20% (D. Ding et al. 2015b)	2 – 5% (D. Ding et al. 2015b)	~ 70% (Ríos et al. 2018)
Dimensional Accuracy (mm)	± 0.04 (Gu 2015)	± 0.05 (D. Ding et al. 2015a)	± 0.13 (D. Ding et al. 2015b)	± 0.2 (D. Ding et al. 2015b)
Build Rates (for Ti6Al4V) (Kg/h)	0.1 – 0.18 (Bhavar et al. 2014)	0.26 – 0.36 (Dutta & Froes 2017)	0.1 – 1.41 (Dutta & Froes 2017)	0.5 – 4 (Williams 2016b)
Maximum Build volume (mm x mm x mm)	500 x 350 x 300 (Bhavar et al. 2014)	200 x 200 x 180 (Bhavar et al. 2014)	900 x 1500 x 900 (Frazier 2014)	Potentially unlimited (Williams 2016b)
Layer Thickness (µm)	20 – 100 (Gu 2015; Ruban et al. 2014)	~ 100 (Murr et al. 2012)	500 – 1000 (Dutta & Froes 2017)	1000 – 2000 (S. W. Williams et al. 2016)
Surface Roughness (µm)	4 – 11 (Vayre et al. 2012; Gu 2015)	25 – 35 (Vayre et al. 2012)	20 – 50 (Gu 2015; Dutta & Froes 2017)	500 (S. W. Williams et al. 2016)
Minimum feature Size (µm)	40 – 200 (Bhavar et al. 2014)	100 (Bhavar et al. 2014)	150 – 200 (Mahamood et al. 2013)	2000 (Williams 2016)

Comparison of four AM processes

[i] *3D Printing Metal Market Size, Share & Trends Analysis Report By Product (Titanium, Nickel), By Form (Filament, Powder), By Application (Aerospace & Defense, Medical & Dental), By Region, And Segment Forecasts, 2021 – 2028, Grand View Research, October 2021*

[ii] *ibid*

[iii] *A comparison framework to support the selection of the best additive manufacturing process for specific aerospace applications. Alberto Garcia-Colomo, Dudley Wood, Filomeno Martina and Stewart W. Williams, International Journal of Rapid Manufacturing, 2020.*



Aluminium nose cone manufactured by WAAM3D and Aircraft Research Association Ltd (ARA) using Wire Arc Additive Manufacturing process

SES appoints Adel Al-Saleh as CEO

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SES has announced that Adel Al-Saleh has been hired as the company's Chief Executive Officer, effective February 2024.

Since January 2018, Al-Saleh has been CEO at T-Systems International GmbH, the integrated IT services provider and subsidiary of telecommunications company Deutsche Telekom AG (DT), and he has served as a member of the Board of Management at DT throughout this period. In his time at T-Systems, Al-Saleh led the transition from a classic information technology and outsourcing business to an integrated IT services and digital solutions provider while driving growth initiatives to optimize operations, improve efficiency, increase customer satisfaction, expand employee engagement and maximise profitability.

Interim SES CEO Ruy Pinto, who served as SES's Chief Technology Officer from 2019 to 2023, will continue to lead SES through January 2024, after which Pinto will remain as a member of the executive team until June 2024 and then will assume the role of strategic advisor to the CEO. Milton Torres, who succeeded Pinto as CTO on an interim basis, will continue in that capacity going forward.

Frank Esser, Chairman of the SES Board of Directors, said, "We are delighted to welcome Adel Al-Saleh as our new CEO. Adel brings a wealth of knowledge, experience and enthusiasm from a range of dynamic, technology-based industries and has a track record of creating value by improving competitiveness and driving efficiency wherever he has been. This makes Adel the ideal person to lead SES into the next phase of our journey and deliver success."

Esser continued, "On behalf of the Board, I want to thank Ruy for his continuing leadership. Ruy stepped in at a critical time and has provided the kind of leadership to allow SES to perform at a high level on behalf of our customers. We look forward to SES continuing under his direction for the balance of this important year and benefitting from his experience and knowledge as we transition to Adel in 2024."

Prior to his time with T-Systems, Al-Saleh led a number of organisations with a track record of achievement. He spent nearly 20 years with IBM in multiple senior leadership roles, culminating in 2006 as Vice President and General Manager, Sales and Industries, IBM Northeast Europe Integrated Operating Team, where he was responsible for IBM's sales across all industries and products. In 2007, Al-Saleh joined IMS Health as President, EMEA, and eventually was named as the company's President, United States. In 2011, KKR-owned Northgate Information Solutions (NIS) Group appointed Al-Saleh as CEO, where he led the transformation of the strategy, portfolio and operations of the NIS Group.

"I am excited and honoured to be joining SES. The business is well placed for the future with world-class customer solutions, differentiated capabilities and an industry-leading financial position. I am looking forward to working with a strong team of colleagues to drive SES forward and create value in an exciting and rapidly evolving market environment," Al-Saleh said.

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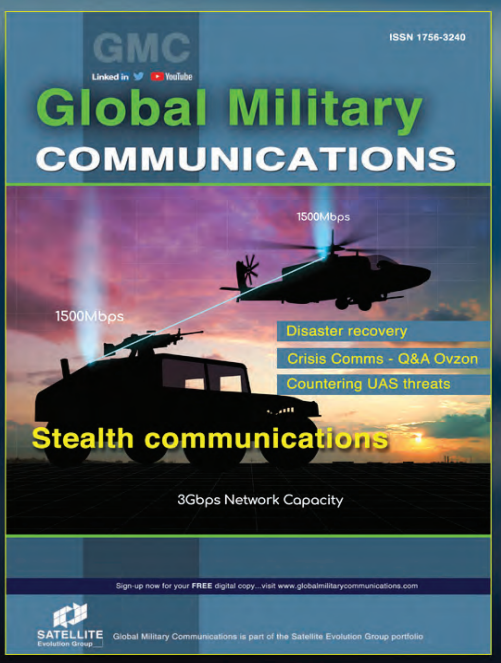

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ST Engineering iDirect announces two new strategic appointments

ST Engineering iDirect has announced two new strategic appointments to its leadership team. Sridhar Kuppanna has been appointed as its new Senior Vice President of Engineering. With over 25 years of experience in managing global R&D teams, driving innovation and bringing new products to market, Kuppanna will focus on the development and delivery of ST Engineering iDirect's next generation platform. He joins from Ribbon Communications where he held responsibilities for delivering industry-leading Secure Cloud Communications solutions to service providers and large enterprise customers around the world.

Cynthia Harty, Senior Vice President of Corporate Strategy, has been appointed to the leadership team. Leading the Corporate Strategy team, Harty will focus on standards-based innovation, strengthening industry relationships and expanding ST Engineering iDirect's presence in the broader telecommunications ecosystem. In her 23 years with ST Engineering iDirect, Harty has held multiple leadership roles across sales, strategy and business development, contributing to its growth.

Don Claussen, ST Engineering iDirect CEO, said, "In this rapidly evolving satellite landscape, we remain focused on our mission - to unite GEO, LEO and MEO and seamlessly integrate with the terrestrial environment as we transition our products and capabilities to software-defined networks. Our commitment is unwavering; we will lead the charge in establishing industry standards to enable a global, multi-domain, cloud-enabled telecom model for our customers.

Cynthia Harty, Senior Vice President of Corporate Strategy

Sridhar Kuppanna, Senior Vice President of Engineering

Sidus Space announces appointment of Leonardo Riera to Board Chair and promotion of Jared Novick to Chief Operating Officer

Sidus Space has appointed Leonardo Riera to the position of Chair of the Board of Directors and promoted Jared Novick to the role of Chief Operating Officer ("COO").

Mr. Riera, currently a Director of Sidus, was appointed as Chair of the Board, effective Thursday, September 14, 2023. It is expected that Mr. Riera will deploy his significant Board experience to manage governance and related matters. Additionally, this change will allow Sidus's CEO, Founder, and former Chair, Carol Craig, to continue leading the company in its successful expansion and meet its primary goals and objectives.

Mr. Riera brings more than 35 years of experience in investment banking and fund management to Sidus. During his accomplished career, Mr. Riera has served as a Consultant for McKinsey & Co, as Head of a Mergers & Acquisitions unit for Citicorp Investment Bank, was the Country Head for Bankers Trust in Venezuela for over 10 years, and subsequently worked in fund management with Intl Consilium and as an entrepreneur. Mr. Riera, who has served on the boards of many private and public companies, currently serves on the Board of Directors of Vaya Space, Inc. and FenixOro Gold, where he also chairs the Audit Committee. He has an MBA from the Wharton School of Business at the University of Pennsylvania and has completed additional education for Senior Executives at the Harvard Business School.

Jared Novick has been promoted to the role of COO, from his prior role as Senior Vice President, Strategy and Special Projects. Most recently, Mr. Novick led Sidus' acquisition of Exo-Space, a space-based AI company, and has worked its post-close integration into newly planned service offerings for Sidus. Mr. Novick's past experience includes government work across the Intelligence Community and Department of Defense where he developed and demonstrated special capabilities and working at NASA in high-altitude programs operating geospatial technologies. Mr. Novick brings prior business experiences as founder and CEO building companies with subscription revenue business models in both Aerospace & Defense and Cybersecurity sectors. He presently sits on the Board of Advisors at BlueVoyant, a unicorn cybersecuirty company.

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