Worldwide Satellite Magazine — February 2019

SatMagazine

Special SmallSat Symposium issue

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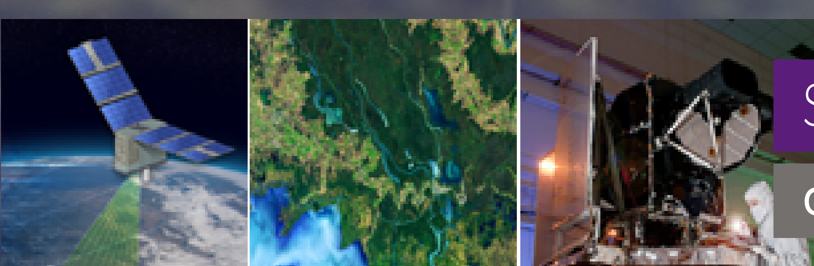
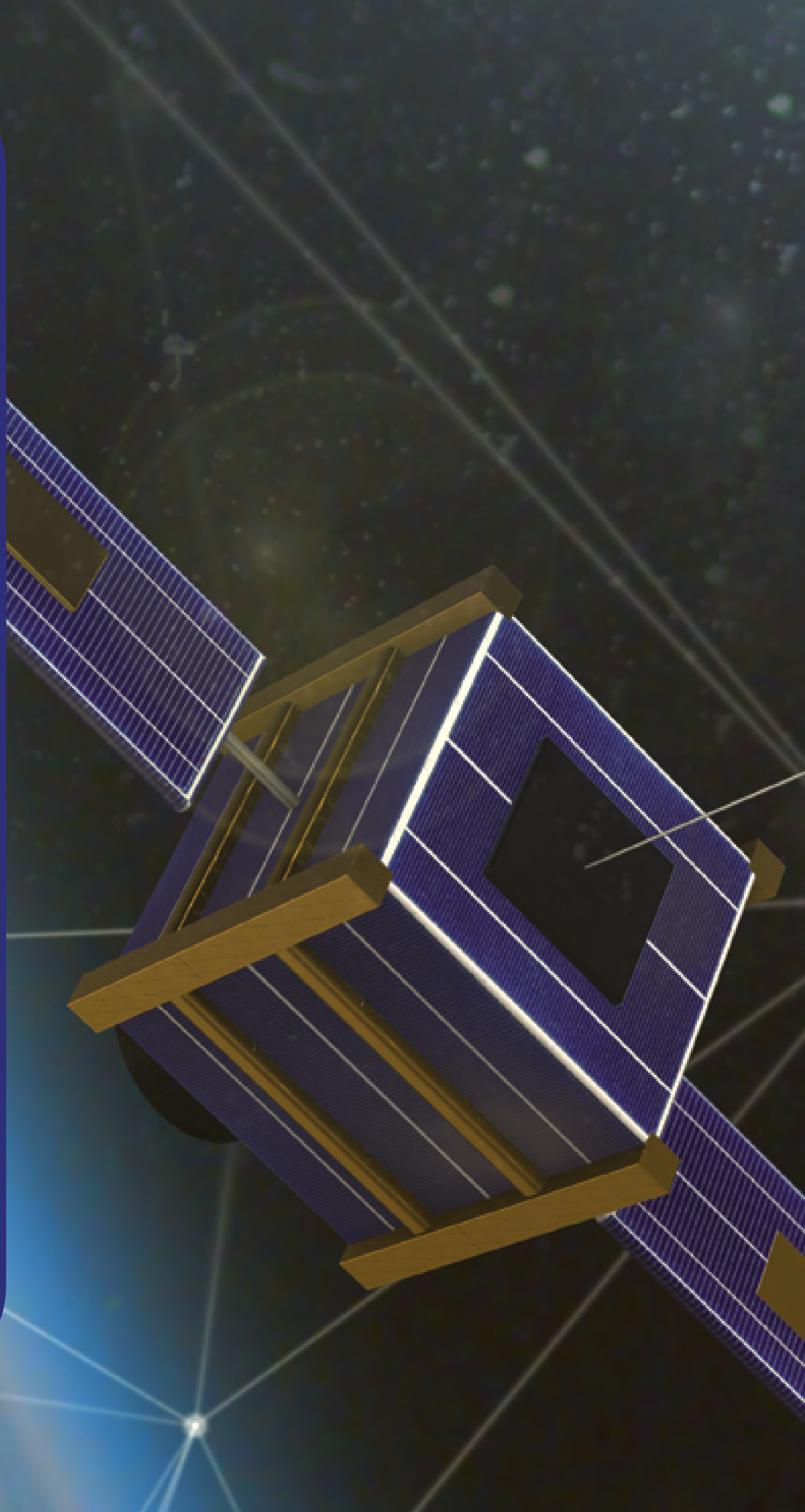
Constellations
EO + Imagery



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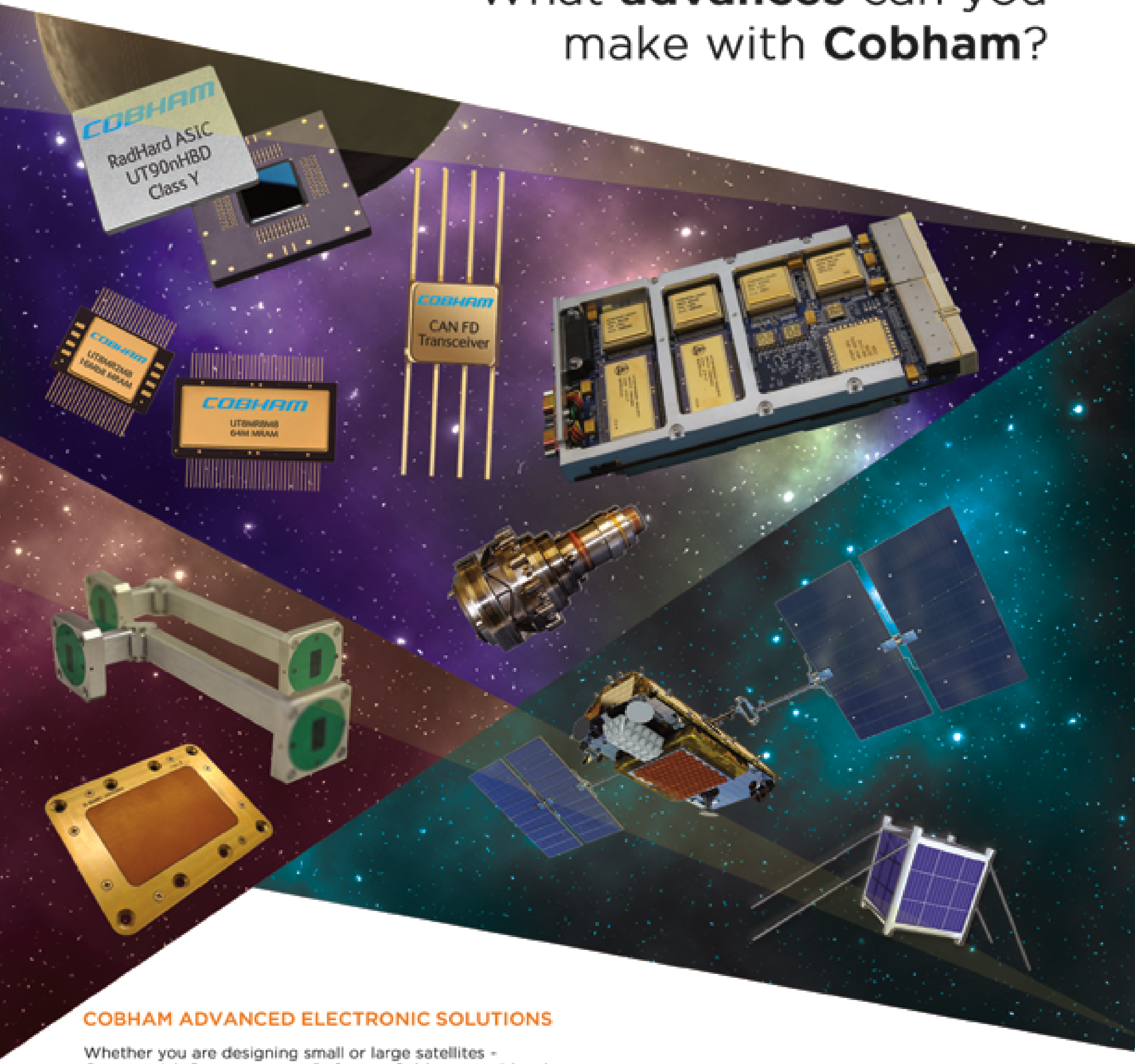

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InfoBeam

On orbit Hawkeye 360 Pathfinder smallsats now activated

Space Flight Laboratory (SFL) announced the in-service activation success of the company's three, formation-flying smallsats that were built by SFL under a contract to Deep Space Industries (now integrated into Bradford Space) for HawkEye 360 Inc.

The smallsats were launched last year into LEO on December 3, 2018, from Vandenberg Air Force Base, California.

The HawkEye 360 Pathfinder smallsats will detect and geolocate radio frequency (RF) signals from VHF radios, maritime radar systems, automatic identification system (AIS) beacons, VSAT terminals and emergency beacons. HawkEye 360 will apply advanced RF analytics to this data to help customers assess suspicious vessel activity, survey communication frequency interference, and search for people in distress.

SFL was selected for the mission by Deep Space Industries, the HawkEye 360 Pathfinder prime contractor, due to the importance of formation flying by multiple satellites for successful RF signal geolocation and analysis. SFL first demonstrated on orbit formation control with smaller satellites in the 2014 with the Canadian CanX-4/CanX-5 mission.

SFL built the three Pathfinder satellites using its space-tested 15 kg. NEMO smallsat bus and incorporated several technologies that make on orbit formation flying possible.

Most prominent of these is the high-performance attitude control system developed by SFL to keep smallsats stable in orbit. Included in the formation flying system are a GPS receiver and a high efficiency Comet-1 propulsion unit developed by Deep Space Industries.

Precise formation flying is critical to the HawkEye 360 RF system because the relative positions of each satellite in the constellation must be known to accurately geolocate the transmission sources of the radio frequency signals.

For the triangulation to be calculated correctly, each satellite must be located with sufficient precision in space and also be relative to one another.

John Serafini, the CEO of HawkEye 360, said this is the first time a commercial company has used formation-flying satellites for RF detection.

SFL Director Dr. *Robert E. Zee* added that the company has developed compact, low-cost formation flying technology that no other small satellite developer can credibly offer.

By leveraging SFL's highly successful formation flying technology demonstrated on orbit, along with DSI's pioneering innovations and next-generation propulsion systems, the mission will deliver unparalleled performance in smaller, affordable satellites

Chris DeMay, the HawkEye 360 CTO and Founder, noted that the core of the firm's business is RF analytics, which is dependent upon high-quality, geolocated RF data.

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www.he360.com


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Hera mission now includes smallsats

When ESA's planned Hera mission journeys to its target binary asteroid system, it will not be alone.

The spacecraft will carry two tiny CubeSats for deployment around — and eventual landing on — the Didymos asteroids. Each companion spacecraft will be small enough to fit inside a briefcase, as compared to the desk-sized Hera.

Hera has room to deliver two 'six-unit' smallsat missions to the Didymos asteroid system — a 780 meter-diameter, mountain-sized main body that is orbited by a 160 meter moon, informally called 'Didymoon,' about the same size as the Great Pyramid of Giza. The Hera mission received proposals for CubeSats from across Europe and an evaluation board has now made the final selection.

The first CubeSat companion is called the Asteroid Prospection Explorer (APEX), and was developed by a Swedish/Finnish/Czech/German consortium. It will perform detailed spectral measurements of both asteroids' surfaces — measuring the sunlight reflected by Didymos and breaking down its various colors to discover how these asteroids have interacted with the space environment, pinpointing any differences in composition between the two.

In addition, APEX will make magnetic readings that will give insight into their interior structure of these bodies. Guided by a navigation camera and a 'laser radar' (lidar) instrument, APEX will also make a landing on one of the asteroids, gathering valuable data in the process using inertial sensors, and going on to perform close-up observations of the asteroid's surface material.

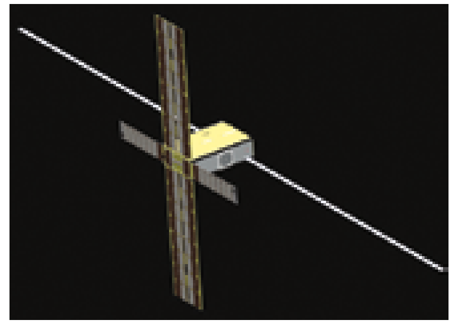
The Asteroid Prospection Explorer (or 'APEX') CubeSat to accompany the Hera mission to the Didymos binary asteroid system.
Photo is courtesy of the Swedish Institute of Space Physics.

The other CubeSat is called Juventas, developed by Danish company GomSpace and GMV in Romania, and will measure the gravity field as well as the internal structure of the smaller of the two Didymos asteroids.

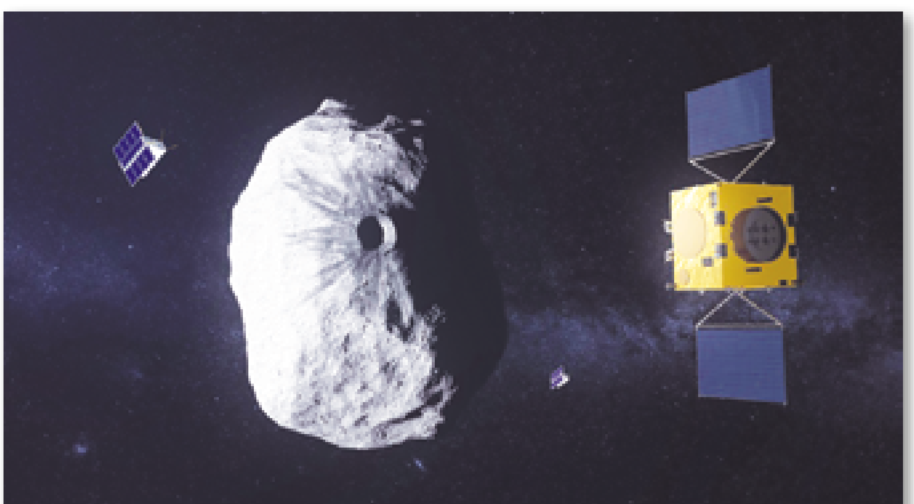
In close orbit around Didymoon, Juventas will line up with Hera to perform satellite-to-satellite radio-science experiments and carry out a low-frequency radar survey of the asteroid interior, similar to performing a detailed 'X-ray scan' of Didymoon to unveil its interior.

The adventure will end with a landing, using the dynamics of any likely bouncing to capture details of the asteroid's surface material — followed by several days of surface operations.

Hera is set to be humankind's first mission to a binary asteroid system. As well as testing technologies in deep space and gathering crucial science data, Hera is designed to be Europe's contribution to an international planetary defense effort: it would survey the crater and measure orbital deviation of Didymoon caused by the earlier collision of a NASA probe, called DART. This unique experiment will validate the asteroid deflection technique referred to as kinetic impactor, enabling humankind to protect our planet from asteroid impacts.



Artistic rendition of Juventas, the 6U CubeSat developed as a 'daughter' to the Hera mothership. Image is courtesy of GomSpace.



ESA's Hera mission artistic concept, currently under study, would be humanity's first mission to a binary asteroid: the 800 m-diameter Didymos is accompanied by a 170 m-diameter secondary body. Hera will study the aftermath of the impact caused by the NASA spacecraft DART on the smaller body. Image is courtesy of the ESA Science Office.

Next, the two CubeSats will have their designs refined and interfaces with their mothership finalized, in line with continuing design work on the Hera mission itself, which will be presented to ESA's Space19+ meeting towards the end of this year, where Europe's space ministers will take a final decision on flying the mission.

Hera manager *Ian Carnelli* explained that the company is very happy to have these high-quality CubeSat missions join with the firm to perform additional bonus science alongside their Hera mothership. Carrying added instruments and venturing much closer to the target bodies, they will give different perspectives and complementary investigations on this exotic binary asteroid. They will also give the company valuable experience of close proximity operations relayed by the Hera mothercraft in extreme low-gravity conditions. This will be very valuable to many future missions.

Paolo Martino, Hera spacecraft lead engineer, added that the idea of building CubeSats for deep space is relatively new, but was recently validated by NASA's InSight landing on Mars last November, when a pair of accompanying CubeSats succeeded in relaying the lander's radio signals back to Earth — as well as returning imagery of the Red Planet.

www.esa.int/Our_Activities/Space_Engineering_Technology/Hera

InfoBeam

Infostellar to provide improved ground station access

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

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

By integrating this ground station with Infostellar's StellarStation service, organizations will be able to remotely access the Goonhilly station for uplink and downlink.

The Catapult will also be able to share unused capacity with the StellarStation network to give greater access to their Goonhilly facility for UK companies.

As a result of this collaboration, Infostellar plans to open a UK office at the Satellite Applications Catapult's Harwell base in 2019.

The UK office will focus on business development and regulatory affairs for Infostellar's international expansion plans in Europe.

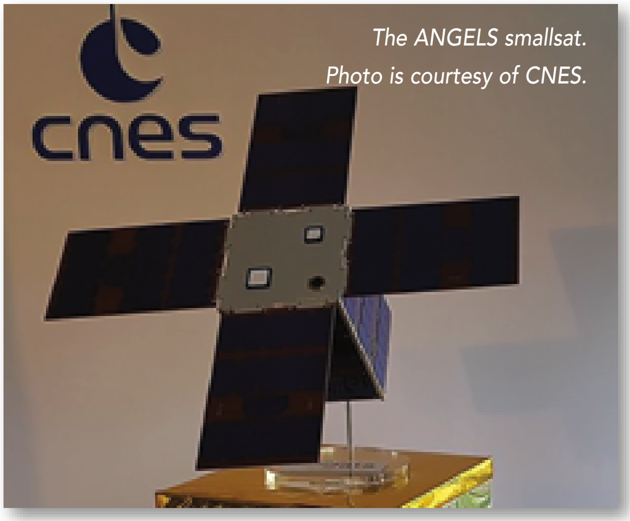
With this agreement, the Satellite Applications Catapult continues to support innovative solutions for the small satellite community, as well as continuing to foster strong links between space companies in the UK and Japan.

Stuart Martin, CEO of the Satellite Applications Catapult said that the Satellite Applications Catapult is thrilled to sign this new agreemen with Infostellar.

This will enhance the company's offering for large and small UK companies and make the Goonhilly ground station more available to participants in the firm's In-Orbit Demonstration program and the wider space community.

Martin added that this is also another excellent example of how the strength of the space sector in the UK continues to generate great interest from innovative international companies.

sa.catapult.org.uk
www.infostellar.net



The ANGELS smallsat. Photo is courtesy of CNES.

ANGELS will be launched as an auxiliary payload with the ***COSMO-SkyMed Second Generation*** (**CSG 1**) and *CHEOPS* satellites by a Soyuz rocket in 2019 from the Guiana Space Center, Europe's Spaceport in French Guiana (South America).

This mission is jointly financed and developed by the French **CNES** (Centre National d'Etudes Spatiales) space agency and **NEXEYA (*www.nexeya.com*)**, an innovative industrial group active in the aerospace, defense, energy, rail and automotive markets.

The satellite will be fitted with a miniaturized ARGOS Néo instrument, which is 10-times smaller than the equivalent previous-generation device.

The instrument collects and determines the position of low-power signals and messages sent by the 20,000 ARGOS beacons now in service worldwide.

Two project teams — CNES and NEXEYA for ANGELS, and CNES, Thales Alenia Space and Syrlinks for ARGOS Néo — are working together on this French space project.

The ANGELS smallsat will have a liftoff mass of approximately 30 kg. at launch, including its separation device, and will be positioned in Sun-Synchronous Orbit (SSO) at an altitude of more than 500 km.

Marie-Anne Clair, CNES Director of Orbital Systems,said that CNES has been committed to miniaturizing satellites for a number of years, in particular through the Proteus mini-satellite and Myriade micro-satellite programs. ANGELS pursues and amplifies this initiative, by paving the way for French industry to build operational nanosatellites within the NewSpace environment.

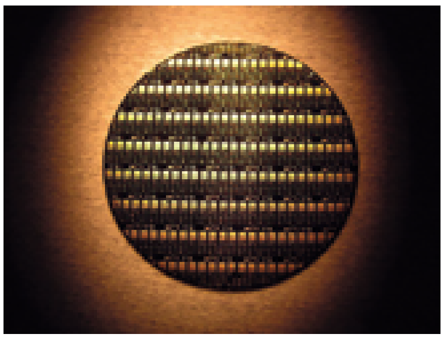
Stéphane Israël, CEO of Arianespace, added that Arianespace is proud of winning this new contract from CNES to launch ANGELS. Against the backdrop of a dynamic small satellite market, this first nanosatellite from French industry reflects the availability of Arianespace's services and its ability to adapt to the needs of the market.

InfoBeam

FCC license for satellite launch received by Akash Systems

Akash Systems, Inc. has been granted an Experimental Special Temporary Authority (STA) license from the Federal Communications Commission (FCC) for a satellite launch featuring its proprietary GaN-on-Diamond transmitter technology.

The GaN-on-Diamond technology (***akashsystems.com/technology/***) will be integrated into a Ka-band (17.2 to 20.2 GHz) 3U radio transmitter and launched in a 12U CubeSat allowing for new levels of data transmission for customers to increase capacity and reduce end-user costs.



The company's satellite launch will demonstrate the transmitter's capability to handle more than five gigabits per second (5Gbps+) downlink speeds from a 10 Watt 3U radio transmitter.

Tentatively slated for early 2020, the launch will validate the data rates, reliability and space-qualification readiness of the GaN-on-Diamond transmitter technology.

The new technology enables a smaller, lighter and higher performing satellite that will pave the way to lower launch costs, reduced cost-per-bit, more launch cycles, and increased communications access around the Earth.

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Akash will continue to focus on scaling up and qualifying its GaN-on-Diamond Power Amplifier product line, offering customers products with higher frequencies that will be announced in the months ahead.

Co-founder, CEO and GaN-on-Diamond Inventor *Felix Ejeckam* said that taking the lead in the satellite communications industry, this demo will showcase the use of the company's proprietary GaN-on-Diamond Radio Frequency (RF) amplifier technology.

He added that beyond the capability to handle the increasing demands of today's extreme data throughput, the firm is confident future adoption of the system will drive down end-user costs to levels never before seen.

Jeanette Quinlan, Director of Space Systems, Akash Systems, added that anyone buying the company's solid-state power amplifiers (SSPAs) to transmit data to or from space will be interested in the space worthiness and reliability of the firm's SSPA products. This launch helps Akash Systems capture that worthiness and reliability data for them.

akashsystems.com

Artistic rendition of Akash Systems' McNair 12U CubeSat. Image is courtesy of Blue Canyon Technologies.

InfoBeam

Newtec providing Kacific with Dialog® VSAT platform

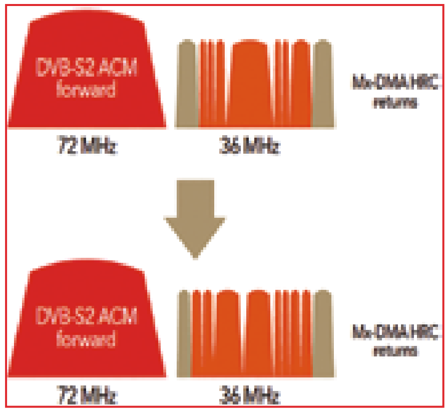
Newtec's Dialog® VSAT multi-service platform has been selected by broadband satellite operator, Kacific, for that firm's new, High Throughput Satellite, to significantly expand that firm's broadband service delivery in underserved areas of South East Asia, New Zealand and the Pacific Island.

The initial contract is for $10 million of Newtec Dialog hubs and this is expected to result in further terminal procurements totaling several million units during the first years of service.

Kacific1 will deliver affordable, high-speed internet broadband to telecommunications companies, internet service providers and governments throughout the region, with Newtec's ***Mx-DMA***® (***www.newtec.eu/technology/mx-dma***) return technology providing the highest bandwidth efficiency.

The Kacific1 satellite features 56 high power subscriber spot beams, each with the capability to provide targeted capacity at high speeds.

Kacific services enable access to high demand applications, such as community internet access and mobile backhaul, that will help stimulate socio-economic activity throughout the region.



The Mx-DMA waveforms. Image is courtesy of Newtec.

Public institutions will benefit from dedicated services including healthcare, education and civil defense, in areas that are beyond the economical reach of terrestrial infrastructures in most of Kacific's coverage areas.

Kacific was recently presented with the SSPI *Better Satellite World* award for its focus on connecting underserved populations.

Newtec's next-generation Mx-DMA return technology incorporates the best features of MF-TDMA and SCPC technologies to provide dynamic bandwidth allocation with the highest level of efficiency.

Mx-DMA return technology on the Newtec Dialog platform uniquely adjusts the frequency plan, the symbol rate, the modulation, coding and power in real-time for every terminal in the satellite network in response to traffic demand and Quality of Service (QoS) changes.

Christian Patouraux, CEO and Founder of Kacific, said the Kacific HUB, based on the Newtec Dialog multi-service platform, is a pivotal part of the satellite network. The company selected Newtec because the firm demonstrates the highest performance and ability to offer the highest link efficiencies that are required for Kacific's Ka-band spot beam system.

Patouraux noted that the company also been impressed with other unique features offered by Newtec, such as the Satellite Network Calculator, which enables the company to tailor new services in a highly efficient and fast-to-market manner, which will only help ensure the reliability and enhance the quality of Kacific services to customers.

Thomas Van den Driessche, CEO at Newtec, added that in partnering with Kacific, the company is strengthening the firm's presence in South East Asia and the Pacific. This project bridges the digital divide to people in regions that have never before had access. Among many other features, Newtec's Satellite Network Calculator has an acute ability to provide valuable insight into the performance of the network.

He continued by saying that the product use in a multi-beam satellite network such as this will allow Kacific to harness these insights to optimize future deployments and add value for their regional partners and customers.

www.newtec.eu/

kacific.com/

Artistic rendition of the Kacific1 satellite. Image is courtesy of Kacific.

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Arianespace to launch EyeSat + ANGELS to space for CNES

Arianespace and the French CNES have signed a launch services contract for the EyeSat smallsat, an astronomy mission that will study zodiacal light as well as image the Milky Way.

EyeSat is a triple CubeSat-sized smallsat that is designed to study the zodiacal light and image the Milky Way and has three main objectives:

- *Scientific, by observing the zodiacal light in the visible bandwidth, in both polarized and non-polarized modes; and taking a thorough – and global image – of the Milky Way in color*
- *To demonstrate new satellite technologies. These technologies were developed through research efforts by CNES, and are considered sufficiently mature to be incorporated on EyeSat*
- *To train students in space engineering professions.*

The EyeSat smallsat is being financed and developed by the French CNES (*Centre National d'Etudes Spatiales*) space agency within the scope of the Janus project (*Jeunes en Apprentissage pour la réalisation de Nanosatellites des Universités et des écoles de l'enseignement Supérieur*), designed to encourage students in universities and engineering schools to develop their own smallsats.

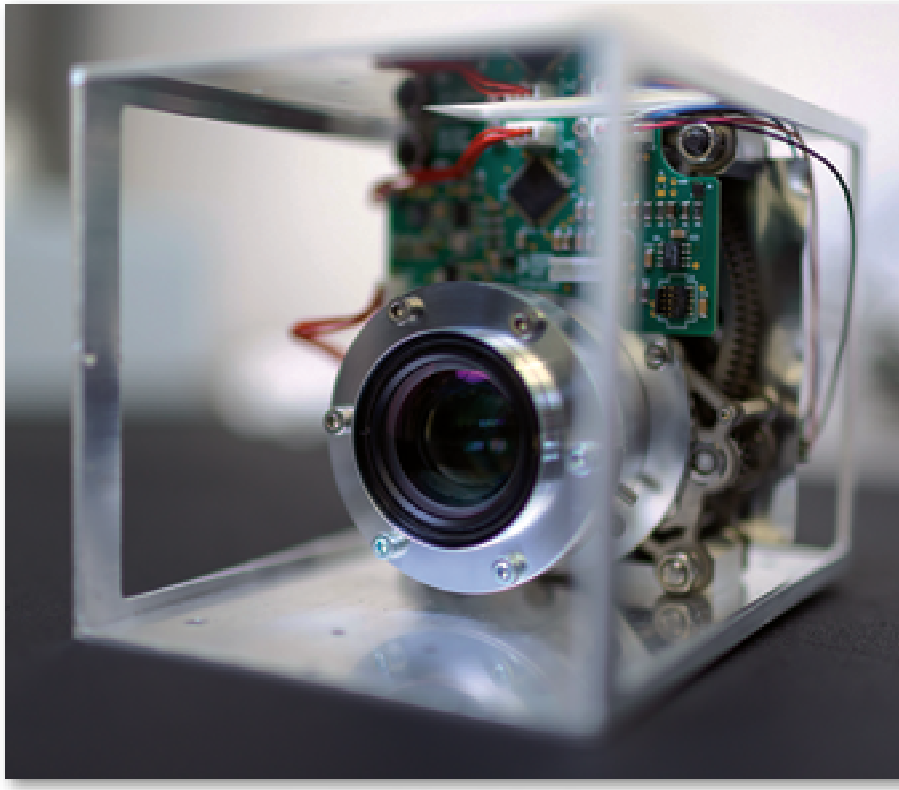


Photo of the IRIS telescape for the EyeSat mission. Photo is courtesy of CNES.

EyeSat will be launched in 2019 as an auxiliary payload with the ***COSMO-SkyMed Second Generation*** (CSG 1) and ***CHEOPS*** satellites from the Guiana Space Center (CSG) aboard a Soyuz launcher.

The smallsat is in the form of a triple (3U) CubeSat and is fitted with an instrument called IRIS, which is a small space telescope.

The smallsat will have a mass at liftoff of approximately 8 kg. and will be placed in Sun-Synchronous Orbit (SSO) at an altitude of about 500 km.

Artistic rendition of the EyeSat smallsat. Image is courtesy of CNES.

Following the contract signature, Marie-Anne Claire, Director of Orbital Systems at CNES, said: "*Thanks to the EyeSat triple CubeSat, CNES will be able to test in orbit a dozen new miniaturized technologies developed through our research and technology program. We also helped train more than 250 students in space engineering professions. CNES is very pleased that EyeSat will be orbited by Arianespace from the Guiana Space Center.*"

Stéphane Israël, Chief Executive Officer of Arianespace, added, "*Arianespace is honored to have been chosen by CNES to launch the EyeSat triple CubeSat dedicated to science. Once again we have proven our ability to guarantee independent and competitive access to space for Europe, encompassing satellites of all sizes, thanks to our flexible service offering and our versatile family of launchers.*"

There's more... the EyeSat contract for Arianespace is not the only business move the firms have signed... a launch contract for the first smallsat completely built by French industry, called *ANGELS* (*ARGOS Néo on a Generic Economical and Light Satellite***), will also be launched by Arianespace.**

www.arianespace.com

cnes.fr

InfoBeam

Final Iridium® NEXT satellites launch is a success...

A liftoff and the Iridium-8 mission's 10 satellites are on their way to LEO, courtesy of the SpaceX Falcon 9.

This is the eighth, and final, set of 10 satellites in a series of 75 total satellites that SpaceX has now launched for Iridium's next generation global satellite constellation, Iridium® NEXT.

Separation has been confirmed and the Falcon 9 also successfully touch downed on the "Just Read the Instructions" droneship stationed in the Pacific Ocean.

To mark the cooperative effort of the companies Matthew Desch, CEO and Director of Iridium, gave the 10 second countdown for the liftoff.

Falcon 9's first stage for the Iridium-8 mission previously supported the Telstar 18 VANTAGE mission in September 2018.

Iridium is deploying 75 satellites to orbit. In total, 81 satellites are being built, with 66 in the operational constellation, nine serving as on-orbit spares and six as ground spares.

Iridium's satellite communications network spans the entire globe and Iridium NEXT is one of the largest "tech upgrades" in space history.

The process of replacing the satellites one by one in a constellation of this size and scale has never been completed before.

The new constellation is enabling innovative new products and services including Iridium Certus℠, the company's next-generation L-band broadband solution for specialized applications, like safety services, remote monitoring, UAV and UAS command and control, tracking, and more.

Also hosted is the Aireon℠ system, which will — for the first time — deliver real-time, truly global aircraft surveillance and tracking.

SpaceX's Space Launch Complex 4E at Vandenberg Air Force Base has a long history of launches, dating back to the early 1960s.

Originally an Atlas launch pad activated in 1962, SLC-4E was in active use until the last Titan IV launch in 2005.

SpaceX's groundbreaking was in July 2011, and extensive modifications and reconstruction of the launch pad were completed just 17 months later.

SLC-4E consists of a concrete launch pad/apron and a flame exhaust duct. Surrounding the pad are RP- 1 and liquid oxygen storage tanks and an integration hangar.

Before launch, Falcon 9's stages, fairing and the mission payload are housed inside the hangar.

A crane/lift system moved Falcon 9 into a transporter erector system and the fairing and its payload were mated to the rocket.

The vehicle rolled from the hangar to the launch pad shortly before launch to minimize exposure to the elements.

Thales Alenia Space comments...

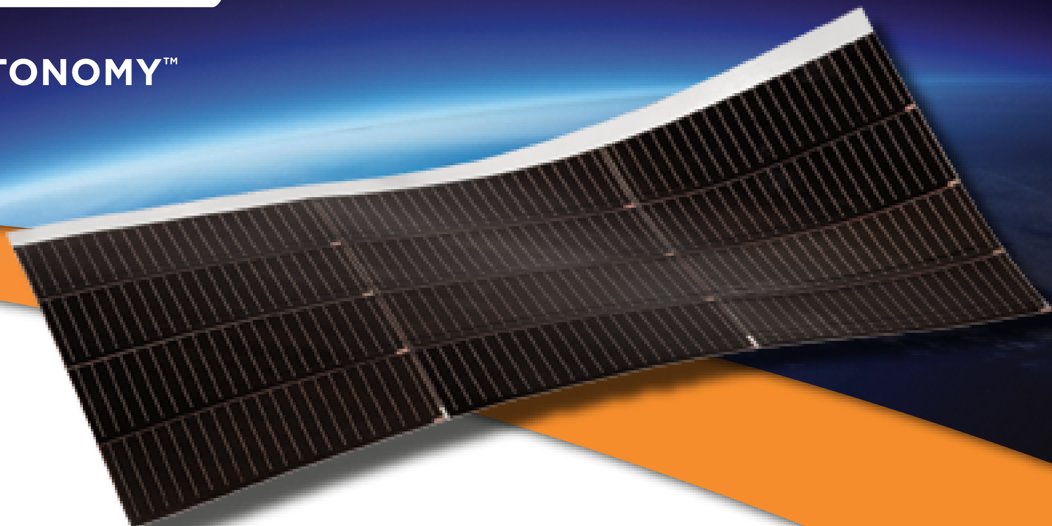
The last batch of Iridium® NEXT satellites, built by Thales Alenia Space, the joint company between Thales (67%) and Leonardo (33%), was successfully launched on January 11 from Vandenberg Air Force Base in California.

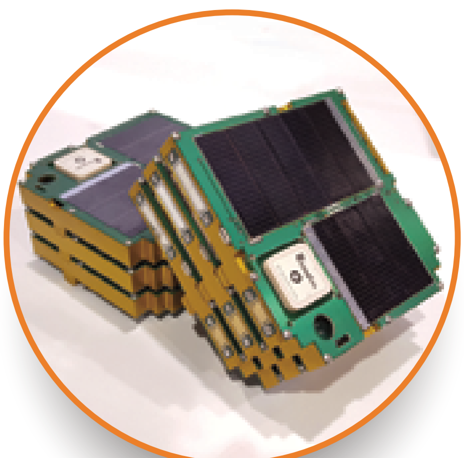
With this successful eighth launch, the Iridium NEXT fleet is now fully deployed to LEO. The operational constellation comprises 66 satellites, at an altitude of about 780 kilometers, organized in six orbital planes, each containing 11 satellites, plus nine spare satellites in a parking orbit and six more ground spares.

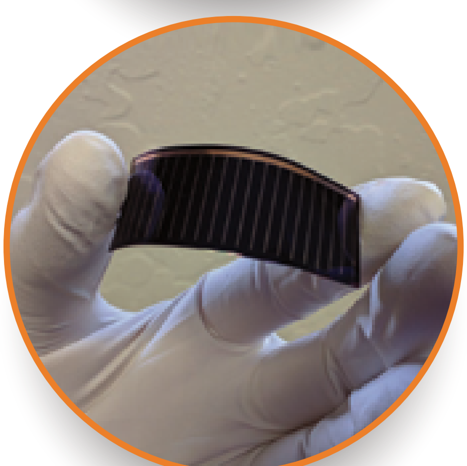
The major challenge for Thales Alenia Space, as prime contractor for the Iridium® NEXT program, was to deploy a complex, end-to-end turnkey satellite system, while also ensuring compatibility between the old and new generations of Iridium Block One satellites.

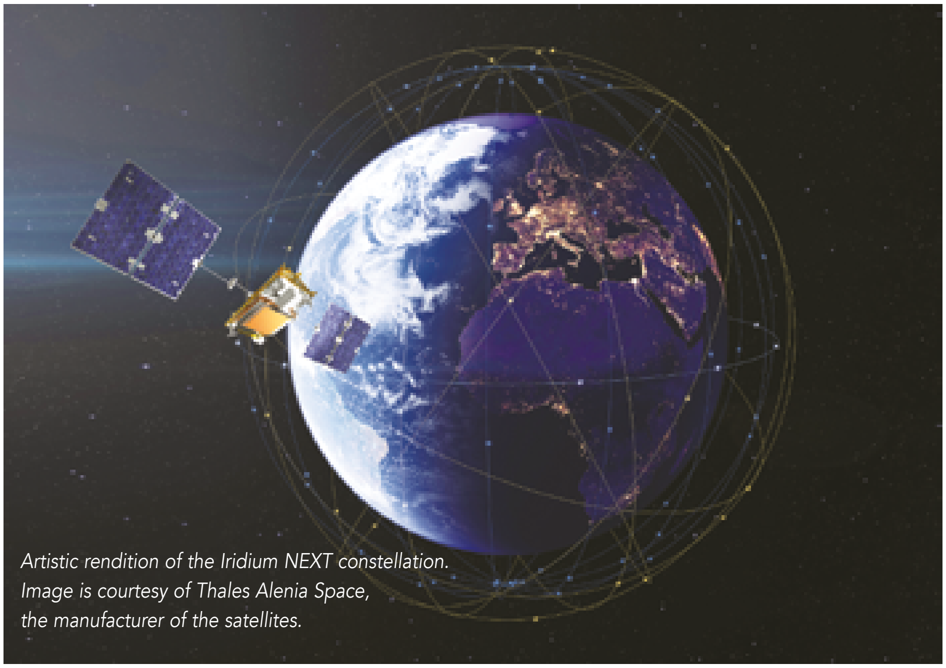
This marks the first time that an operator and a manufacturer have worked hand-in-hand to replace a complete constellation of 66 satellites, one-by-one, without any interruption in user service*.

The Falcon 9 launch of the Iridium-8 mission. Photo is courtesy of SpaceX.









Artistic rendition of the Iridium NEXT constellation. Image is courtesy of Thales Alenia Space, the manufacturer of the satellites.

The Iridium® NEXT constellation, now completely on orbit, represents the current state-of-the-art in terms of technology and flexibility.

The constellation features global coverage and independence from the ground segment, as each satellite is linked to the four closest satellites: in front, behind, to the left and the right. No matter where users are on Earth, they will always be in the line-of-sight of at least one satellite, meaning that they can always establish a connection.

This direct satellite access, whether for transmission or reception, provides communication capability at any given moment, even in the case of natural disasters, conflicts, or in isolated environments. It also ensures secure communications, with protection against intrusion and piracy**.

Denis Allard, VP Constellation Projects at Thales Alenia Space, said that the company is extremely proud of this successful last launch. The company has now delivered a constellation comprising 81 satellites — a daunting challenge, but one that the company's teams met with panache. The success of this program also confirms Thales Alenia Space's global leadership in the constellation market, and further bolsters the company's unrivaled expertise as prime contractor for end-to-end and turnkey complex telecommunications systems.

** Slot swap*
Thales Alenia Space handled satellite positioning and in-orbit testing from Iridium's satellite control center in Leesburg, Virginia, near Washington, D.C. The satellites are launched in clusters of ten and, given their LEO orbit, ground stations have only ten minutes per orbit to send commands while the satellites are visible. This means that all teams had to be exceptionally well prepared and on top of their game to do everything needed during those ten minutes.

Iridium NEXT satellite at Thales Alenia Space manufacturing facility. Photo is courtesy of Thales Alenia Space.

The new satellites are then placed in their final orbital position one by one, before control is handed over to Iridium's teams for the actual "slot swap" operations, handled by Iridium with the support of Thales Alenia Space, based on procedures defined and tested by Thales Alenia Space

Each Iridium® NEXT satellite is fitted with a star sensor from Leonardo that guarantees orbital position-determination and control. The satellites were previously integrated by Northrop Grumman Corporation (the former Orbital ATK), a subcontractor to Thales Alenia Space based in Gilbert, Arizona, supervised by specialized teams from Thales Alenia Space and Iridium.

*** Telecom signal routing in orbit*
Each satellite has links to the four other closest satellites, in front, behind, left and right, making the service completely independent from ground networks. This in-orbit routing is completely software-driven by an onboard processor (OBP) and a platform computer (PFC). These software programs are the most sophisticated used to date on a constellation of satellites. They can also be uploaded from the ground, meaning that ground operators can send updates if needed, as well as deploy higher-performance versions, enabling Iridium to expand and enhance its customer services.

Aireon's Payload Joins ADS-B Payload Family On Orbit

Aireon's space-based Automatic Dependent Surveillance-Broadcast (ADS-B) payload was successfully deployed during the eighth and final launch and positioning of the Iridium NEXT satellite constellation — at 7:31:33 AM PST (15:31:33 UTC) on January 11, a SpaceX Falcon 9 rocket lifted off from Vandenberg Air Force Base in California and placed the final 10 Iridium NEXT satellites into LEO.

This launch brought the total number of Aireon payloads in orbit to 75 (66 operational payloads and 9 spares), completing the historic launch program and passing one of the last remaining milestones before Aireon ushers in a new era of global air traffic surveillance and aircraft tracking.

Aireon is the world's first, 100 percent global air traffic surveillance system and is revolutionizing the way the world travels

Whether the mission demands staying on-air in a 85 mile-per-hour (136 kph) wind storm, a sandstorm, a blizzard, hail, or torrential rains – the **Portable Radome** helps make satellite networks more survivable and deployable into extreme or harsh environments. Gain significant cost saving vs. conventional radomes for military or civilian networks. Heating and air-conditioning options.

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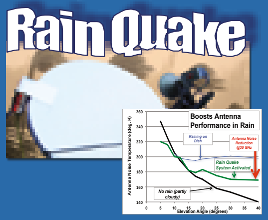

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with space-based technology. Unlike existing aircraft surveillance and tracking infrastructure, the Aireon system uses space-based ADS-B technology, which enables the automatic and real-time collection of aircraft position data.

The Aireon technology gives air traffic controllers and airlines a complete and comprehensive view of the entire sky, like never before. With this upgraded insight into the world's flight paths, including those in remote and oceanic airspace, the entire industry will experience significant direct and indirect benefits such as, increased safety, more efficient flight routes, more accurate arrival and departure predictions, faster emergency response times, reduced aircraft separation, a decrease in CO2 emissions and more.
Thus far, the Aireon system has out-performed all predictions and is processing more than 13 billion ADS-B messages per month, with that number expected to grow upon full deployment. Air traffic controllers rely on the best and most accurate surveillance data possible to separate aircraft, which is often achieved through multiple redundant layers.

Aireon's data will provide air traffic controllers with a fully redundant data feed that covers the entire airspace, increasing the availability and reliability of a critical component in air traffic management, with a positive impact on safety and efficiency. This will in turn, help improve flight optimization by eliminating gaps in fleet data reports, and ultimately enhance the overall safety, accuracy and efficiency of worldwide air travel.

This launch marks the completion of the Iridium NEXT launch campaign, successfully deploying the full Aireon system.

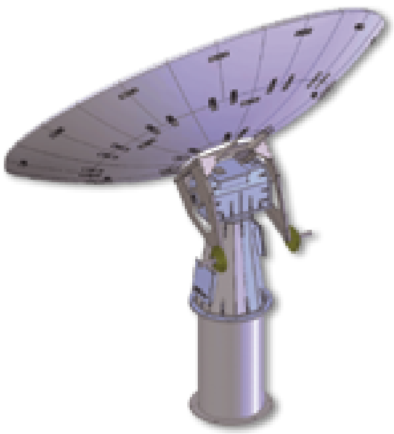
Don Thoma, the CEO of Aireon, said that the company has passed a major milestone on the firms journey to revolutionize air traffic surveillance and the company is just weeks away from a fully operational system. Now that the launches are complete, final integration and testing of the recently launched payloads can commence, after which the world's first, real-time, truly global view of air traffic will be a reality. It's difficult to contain the excitement until all is formally operational, especially as from a performance standpoint, the company's technology has far exceeded expectations. Many may think this is the end of a journey, being the last Iridium NEXT launch; however, for Aireon, this is the start of a new way air traffic will be managed.

Marion Blakey, former Administrator at the Federal Aviation Administration (FAA), added that Aireon's space-based ADS-B network is just what the aviation industry needs. During my time at the FAA, extensive work was done to promote ADS-B technology for global air traffic management efforts. Today's successful launch is a victory for Aireon as well as for the aviation industry — one step closer to having a clear, accurate and complete picture of the world's airspace, including over the oceans and remote areas. (*Blakey now serves on the Aireon U.S. Advisory Board alongside its Chairman, The Honorable Norman Mineta and Vice-Chairman, Russ Chew.*)

www.iridiumNEXT.com
www.spacex.com
www.aireon.com

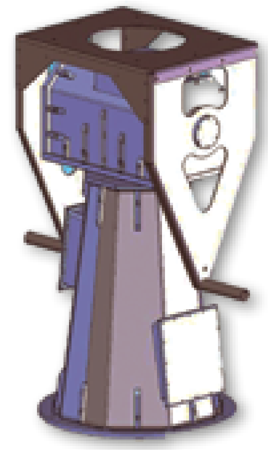
InfoBeam

New antenna control system debuts from Radeus Labs



The M2 Antenna Systems AE2000, AZEL pedestal box frame (SERVO).

Radeus Labs, Inc. has released a new antenna control system to address the growing smallsat/LEO/MEO market.



The Model 2200 Antenna Control System is designed with a feature set to support full motion, LEO and MEO antenna applications.

With velocity control of smart motors, antenna speeds well beyond ten degrees per second are supported.

When coupled with the 2048 Drive Interface, the 2200 is designed for and interfaces seamlessly with M2 Antenna System's latest full-motion pedestal design, the AE-2000S.

The 2200 covers the smallsat bases to the existing infrastructure of GEOs.

Radeus Labs control system products are designed to be easy to install, easy to use and with an eye to extending the life of mechanical system components.

All Radeus Labs Products are backed with excellent delivery, after sales support and a commitment to serve our customers best interest.

The 2200 is commercially released and available for delivery.

Ken Cone, CTO of Radeus Labs, said the company is extremely pleased to introduce the 2200 line of antenna control systems. With this product line, Radeus Labs is increasing the firm's technological capabilities to serve the increasing needs of SATCOM customers.

www.radeuslabs.com

www.m2inc.com

InfoBeam

Thales Alenia Space sees green

Thales Alenia Space has received a vote of confidence with their most recent contract from the European Space Agency (ESA) to lead the Fluorescence Explorer (FLEX) satellite mission.

Thales Alenia Space signed a contract with the European Space Agency (ESA) to lead the ***Fluorescence Explorer*** (**FLEX**) satellite mission, and is scheduled for launch in 2023. It will make use of an innovative instrument, named FLORIS, to map the Earth's vegetation fluorescence to quantify photosynthetic activity.

Thales Alenia Space is program prime contractor and has also signed a novation agreement to integrate the contract that ESA awarded to **Leonardo** in 2016 concerning the development of the FLORIS instrument. The overall contract is worth approximately 150 million euros.

Thales Alenia Space will be leading a consortium for the FLEX program that includes its own subsidiaries and partners from the space industry.

Thales Alenia Space in the UK will be in charge of the satellite propulsion system, as well as assembly, integration and testing (AIT). Thales Alenia Space in Spain will provide the radio-frequency subsystem, including X-band and S-band transponders, and **RUAG** will contribute to the design and production of the platform.

Leonardo's FLORIS instrument is a high-resolution imaging spectrometer operating in the 500 to 880 nm spectral range. Leonardo is leading a consortium of European companies, including primary partner **OHB System AG**, to deliver the spectrometer.

Operating from an altitude of 800 kilometers, the FLEX instrument will collect the light emitted by plants and break it down into its constituent colors. The sensor can then identify the faint reddish glow emitted during photosynthesis, normally invisible to the naked eye, and precisely identify the fluorescence of vegetation, allowing researchers to evaluate the health of Earth's ecosystem.

Marc Henri Serre, head of the Observation and Science domain at Thales Alenia Space in France, said that this contract is the culmination of Thales Alenia Space's development strategy in Europe, including their ability to submit the first full consortium offer for ESA that integrates the industry consortium very early in the process.

He noted that the FLEX program is the latest reflection of their strong commitment to environmental programs and a perfect illustration of their company's watchword, 'Space for Life.'

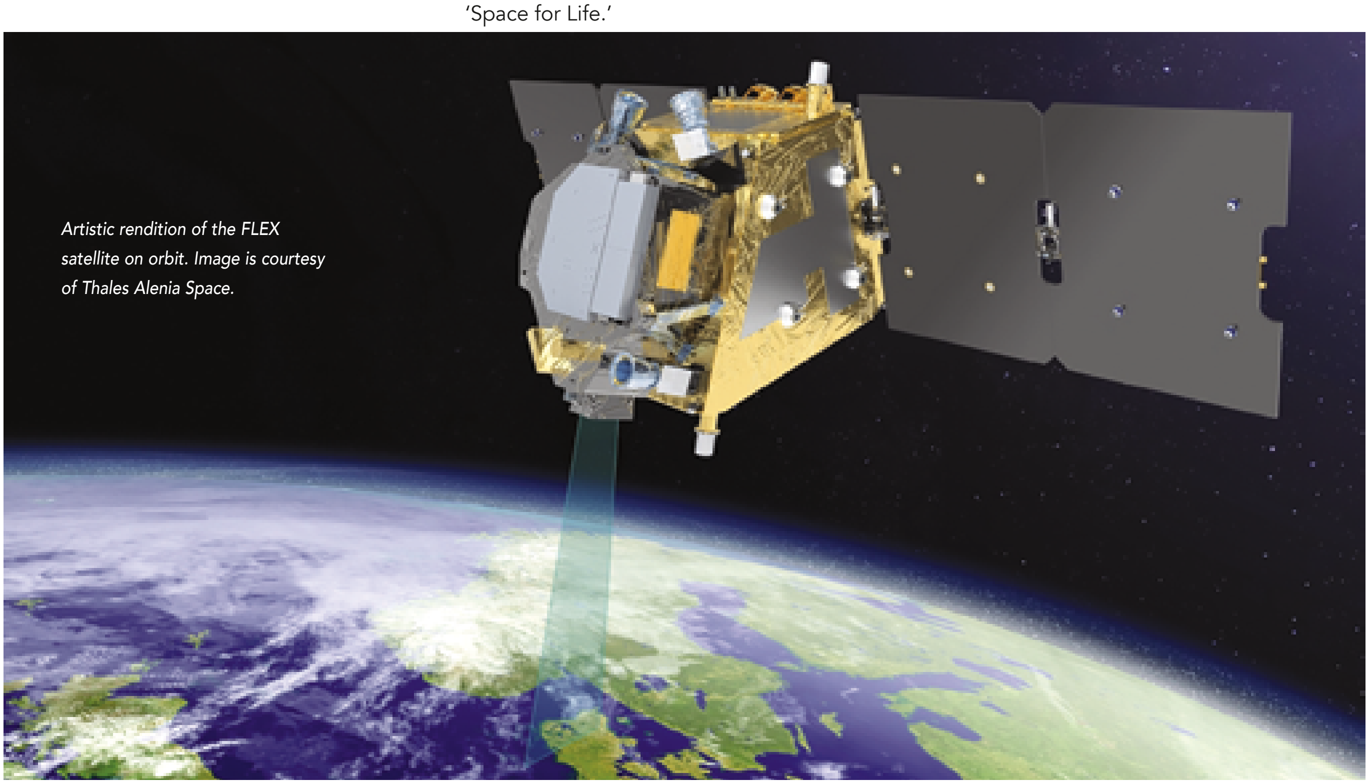
The conversion of atmospheric carbon dioxide and sunlight into energy-rich carbohydrates through photosynthesis is one of the most fundamental processes on Earth — and one on which life depends. Information from FLEX will improve the understanding of how carbon moves between plants and the atmosphere and how photosynthesis affects the carbon and water cycles.

In addition, information from FLEX will give a better insight into plant health. This is especially important today since the Earth's growing population is placing increasing demands on the production of food and animal feed.

The FLEX satellite will orbit in tandem with one of the ***Sentinel-3*** satellites (part of Europe's ***Copernicus*** program), also built by Thales Alenia Space. It will take advantage of Sentinel-3's optical and thermal sensors to provide an integrated package of measurements to assess plant health.

FLEX is to be orbited by an **Arianespace *Vega*** light launcher and will be placed in a *Sun-Synchronous Orbit* (SSO) at an altitude of 815 km., with an expected latency of 24 hours for Level-1 products.

www.thalesgroup.com/en/global/activities/space



Artistic rendition of the FLEX satellite on orbit. Image is courtesy of Thales Alenia Space.

InfoBeam

Orbital Micro Systems and Lemon Advisors to strategize on weather

Orbital Micro Systems (OMS) has formed a strategic relationship with Lemon Advisors, a consultancy focused on international expansion and strategic business development activities, to assist the company in increasing sales of their unique weather intelligence services for commercial and government entities.

Under the leadership of founder *Subhash Ghosh*, Lemon Advisors UK will work closely with OMS to identify and engage key industrial and government customers that can benefit from the unmatched volume and precision of analytics-ready weather observation data generated from OMS's *International Center for Earth Data* (ICED) facility in Edinburgh, Scotland.

Lemon Advisors UK will also contribute local expertise to contractual matters, sales and promotional activities, partnering and alliance opportunities, business formalities, and operational management.

OMS operates a fleet of Earth Observation (EO) satellites that will gather detailed weather data much more frequently and accurately than current government-owned weather satellites.

OMS's ICED platform integrates this data with other public and private datasets to provide simple and timely access to comprehensive weather intelligence within minutes of observation.

The ICED platform empowers decision-making and risk management based on facts, not forecasts.

The data produced from ICED serves a multitude of military, government, and commercial organizations, including customers in insurance, aviation, maritime, energy, and agricultural sectors.

With higher temporal and spatial resolution, refreshed and delivered every 15 minutes, it provides accurate forecasting to enable faster, informed analytics and decision-making and ultimately improving the effectiveness of organizations' forecasting, financial modeling, and operations.

www.orbitalmicro.com

www.lemonadvisors.london/site/

InfoBeam

SSL to define smallsat requirements

SSL, a Maxar Technologies company (NYSE:MAXR) (TSX:MAXR), provider of satellites and spacecraft systems, is combining Maxar's capabilities for a contract to define the requirements to build a small form-factor satellite that will monitor and measure methane emissions from oil and gas facilities around the world.

The satellite, named ***MethaneSAT***, will enable *Environmental Defense Fund* (EDF) to change the way detection and analyzation is established of methane emissions and then to understand and combat climate change.

Following design development, EDF anticipates awarding a contract in 2019 for the final design and manufacturing of the satellite.

To enhance its solution, SSL is working together with Maxar's **DigitalGlobe**, which is the global leader in commercial high-resolution satellite imagery.

DigitalGlobe will provide technical input on the satellite payload design and guidance on the overall mission plan.

MethaneSAT will provide global, high-resolution detection of methane emissions from regions that account for more than 80 percent of global oil and gas production on a weekly basis.

The satellite's high precision will enable it to detect and quantify both high- and low-emission sources and accurately attribute them to relevant oil and gas infrastructure.

Richard White, the President of S**SL Government Systems** said that SSL's decades of experience in developing reliable spacecraft systems, combined with the full suite of space capabilities offered by Maxar Technologies, uniquely positions them to provide solutions for advanced missions, such as MethaneSAT.

He added, "*The company is honored to lead the charge in accelerating innovation for missions that reveal critical insights about their changing planet and help to build a better world.*"

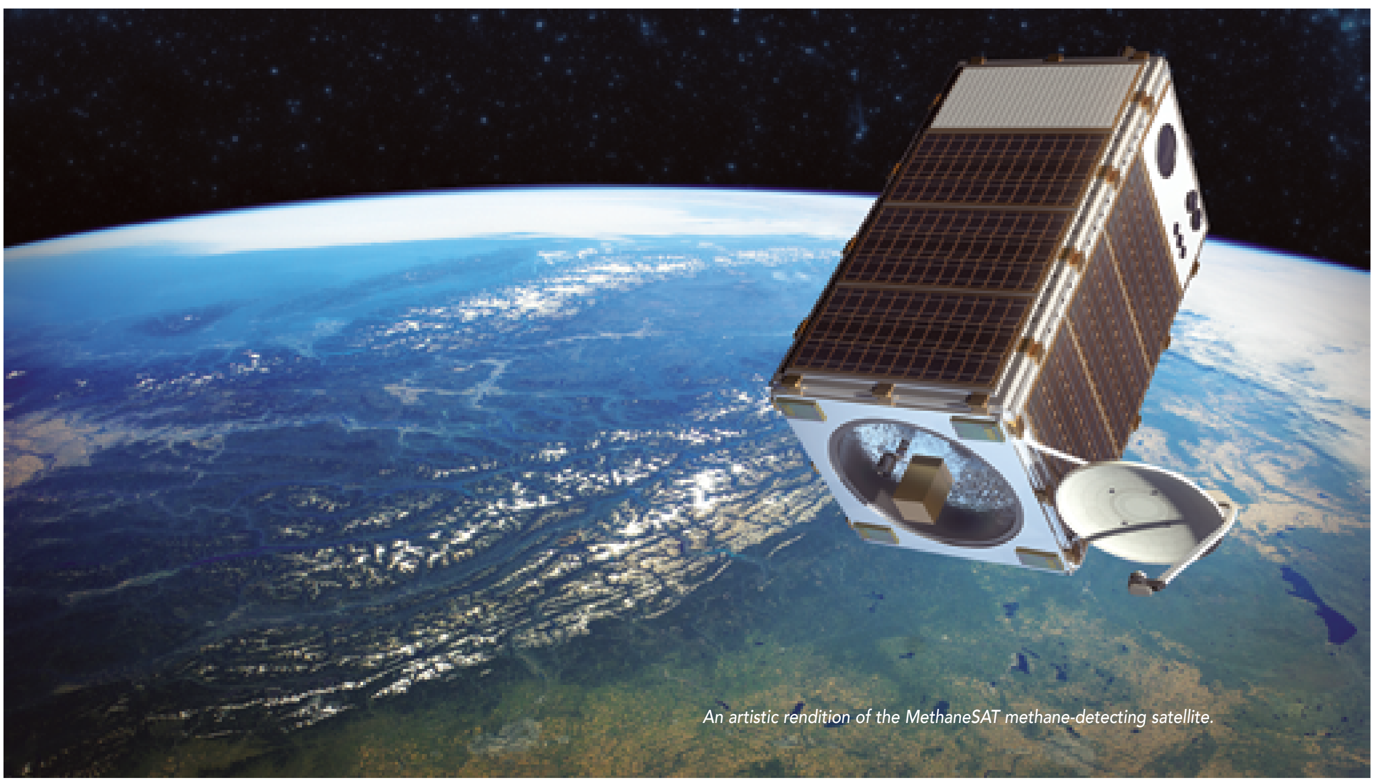
SSL is building momentum in its small form-factor and low Earth orbiting spacecraft business with competitive solutions for government and commercial customers.
In addition to designing MethaneSAT, the company is:

- *Building DigitalGlobe's next-generation, high-resolution WorldView Legion constellation, which will more than double DigitalGlobe's capacity in important regions*
- *Continuing to provide Earth observation satellites to Planet, with 13 SSL-built SkySats currently operating on orbit*
- *Plus, developing small to medium satellite solutions for the U.S. Department of Defense under the Small Spacecraft Prototyping Engineering Development and Integration (SSPEDI) award.*

www.sslmda.com

www.edf.org/climate/how-methanesat-is-different?utm_source=press-release&utm_medium=cision&utm_campaign=methanesat

www.digitalglobe.com/?utm_source=press-release&utm_medium=cision&utm_campaign=methanesat



An artistic rendition of the MethaneSAT methane-detecting satellite.

InfoBeam

World Teleport Association 2018 rankings published

The World Teleport Association (WTA) has published their annual rankings for the Top Teleport Operators of 2018 — the annual rankings of companies by revenue and revenue growth are compiled by surveying teleport operators around the world as well as referencing the published results of publicly-held companies.

"*The 2018 Top Operator rankings are based on data from the last two complete fiscal years: fiscal 2017, in whatever month it ended, and the previous year,*" said Executive Director Robert Bell.

He continued, "*As the industry press has reported, those were the beginning of tough times for GEO satellite operators, as the explosive growth of HTS capacity coincided with market disruption for broadcast distribution. The same trend has challenged top-line revenues for teleport operators, with 50 percent reporting year-over-year revenue declines.*"

Bell noted, "Resale of satellite capacity is a low-margin business for most operators, however, which significantly limits the impact of that decline on EBITDA. But the decline has led us to reduce the number of companies covered by the Top Operators lists to 20 on a global basis, 15 for independent teleport operators and 10 for the fastest-growing operators."

In May of 2019, WTA will publish its annual Inside the Top Operators report that will provide a more detailed analysis of survey results.

The Independent 15

The Independent Top 15 ranks teleport operators based on revenue from all sources.

The list focuses on the independent operators at the core of the business, excluding companies whose primary business is ownership and operation of a satellite fleet or terrestrial network.

In order from largest to smallest, the Independent Top 15 of 2018 are:

- **Speedcast (Australia)**
- **Telespazio (Italy)**
- **Globecast (France)**
- **Arqiva (UK)**
- **Globecomm (USA)**
- **Du (UAE)**
- **PlanetCast (India)**
- **Media Broadcast Satellite (Germany)**
- **Signalhorn Trusted Networks (Germany)**
- **Axesat (Colombia)**
- **Jordan Media City (Jordan)**
- **Elara Comunicaciones (Mexico)**
- **US Electrodynamics (USA)**
- **CETel (Germany)**
- **Global Data Systems (USA)**

The Global Top 20

The Global Top 20 ranks companies based on revenues from all customized communications sources and includes operators of teleports and satellite fleets.

In order from largest to smallest, the Global Top 20 of 2018 are:

- **Intelsat (Luxembourg)**
- **SES (Luxembourg)**
- **Eutelsat (France)**
- **Telesat (Canada)**
- **Speedcast (Australia) ***
- **EchoStar Satellite Services (USA)**
- **Telespazio (Italy) ***
- **Singtel Satellite (Singapore)**
- **Globecast (France) ***
- **Thaicom (Thailand)**
- **Hispasat (Spain)**
- **Arqiva (UK) ***
- **Globecomm (USA) ***
- **Optus (Australia)**
- **AsiaSat (Hong Kong)**
- **MEASAT (Malaysia)**
- **Telenor Satellite (Norway)**
- **Gazprom Space Systems (Russia)**
- **Du (UAE) ***
- **PlanetCast (India) ***

* Independent: does not own or operate satellite capacity

The Fast 10

The Fast 10 ranks all teleport-operating companies based on year-over-year revenue growth in their most recent fiscal years.

Speedcast was the fastest of the fast with 301 percent year-over-year growth driven by major acquisitions. Ranked by revenue growth, the Fast 10 of 2018 are:

- **Speedcast (Australia) ***
- **Globecomm (USA) ***
- **CETel (Germany) ***
- **Elara Comunicaciones (Mexico) ***
- **US Electrodynamics (USA) ***
- **PlanetCast (India) ***
- **AsiaSat (Hong Kong)**
- **Santander Teleport (Spain) ***
- **MEASAT (Malaysia)**
- **Du (UAE) ***

* Independent: does not own or operate satellite capacity

www.worldteleport.org

InfoBeam

Comtech EF Data receives global satellite operator equipment order

Comtech EF Data's CDM-760 Advanced High-Speed Trunking and Broadcast Modem.

Comtech Telecommunications Corp. (NASDAQ: CMTL) has that during the firm's second quarter of fiscal 2019, their Tempe, Arizona-based subsidiary, Comtech EF Data Corp., which is part of Comtech's Commercial Solutions segment, was awarded a $1.0 million infrastructure equipment order from a global satellite operator.

The satellite operator will continue to team Comtech EF Data products with their innovative, global, GEO satellite constellation to offer customers unparalleled performance and reliability.

The order specified Comtech EF Data's ***CDM-760 Advanced High-Speed Trunking and Broadcast Modem***, which offers the user data rates of over one Gigabit per second and was designed to be the market's most efficient, highest throughput, point-to-point trunking and broadcast modem.

The modem leverages 256APSK modulation, DVB-S2X and bi-directional Adaptive Coding and Modulation operation, which is the most advanced combination of space segment saving capabilities that minimize overhead.

The modems will be deployed and used to support next generation, high-speed maritime applications across the satellite operator's global GEO satellite constellation.

Fred Kornberg, President and CEO of Comtech Telecommunications Corporation, said the satellite operator selected the company's satellite modems based on the firm's proven track record of delivering reliable and highly resilient products with the highest speeds in MEO and GEO modes.

www.comtechefdata.com/files/datasheets/ds-CDM760.pdf

InfoBeam

SSTL completes QUANTUM build

Surrey Satellite Technology Ltd (SSTL) has completed the build of the platform for EUTELSAT QUANTUM, the world's first geostationary telecommunications satellite that will be fully reconfigurable in orbit.

The **EUTELSAT *QUANTUM*** satellite is being built under a public–private partnership between the **European Space Agency** (ESA) and the satellite operator Eutelsat with **Airbus** as the prime contractor. The satellite platform, which has been designed and manufactured by **SSTL** in Guildford, was on view to invited guests at a special event to mark the handover to Airbus who will complete the satellite assembly and testing in Toulouse.

The EUTELSAT QUANTUM platform consists of a precision-engineered composite central thrust tube standing at 2.5 meters tall which houses a bipropellant chemical propulsion system that will enable the satellite to stay on station throughout its 15 year lifetime, and SSTL's newly developed GEO momentum wheels and gyro which will maintain the satellite in a stable attitude and enable adjustments in the satellite's orbital position.

Sarah Parker, Managing Director of SSTL said, "*The completion of our work on the EUTELSAT QUANTUM satellite platform is an important milestone for SSTL as it represents*

our first venture into the global commercial telecoms satellite market. The design and assembly of this innovative spacecraft has enabled us to advance the knowledge and skills required to develop highly capable satellite products for the evolving telecoms market, where we are actively engaged in seeking new opportunities."

Colin Paynter, Managing Director, Airbus Defence and Space UK, said: "*Combining the payload expertise from Airbus in Portsmouth, and SSTL's new geostationary platform provides a very sophisticated package for Eutelsat. The satellite is a world first, fully reprogrammable in orbit, and we're looking forward to seeing it fly.*"

The EUTELSAT QUANTUM satellite will be able to adapt to new demands in coverage, bandwidth, power and frequency, enabling it to operate effectively from any orbital slot. EUTELSAT QUANTUM will be the first generation of universal satellites able to serve any region of the world and adjust to new business without the user needing to procure and launch an entirely new satellite. Featuring phased array antennas and flexible connectivity, which is fully reconfigurable in orbit, EUTELSAT QUANTUM will be able to adjust its coverage and capacity to suit customers' needs as and when they change.

Yohann Leroy, Deputy CEO and CTO at Eutelsat said "*EUTELSAT QUANTUM is a world first and the culmination of many years of research by Eutelsat. Its premium capacity will enable us to offer game-changing optionality and flexibility to our customers in the government, mobility and data markets, who will be able to operate and optimize capacity to adjust coverages in real time, and to do so autonomously. We are delighted to co-operate with our long-standing partners, the ESA, the UK Space Agency and Airbus, and to be able to rely on the world-leading expertise within the UK space industry.*"

EUTELSAT QUANTUM uses technology developed by Airbus and SSTL in the UK under the ESA *Advanced Research in Telecommunications Systems* program (ARTES) and supported by the **UK Space Agency.**

https://www.sstl.co.uk

www.eutelsat.com/en/satellites/future-satellites/Eutelsat-Quantum.html

www.esa.int

www.airbus.com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U.S. AIR FORCE
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Commander
AIR FORCE
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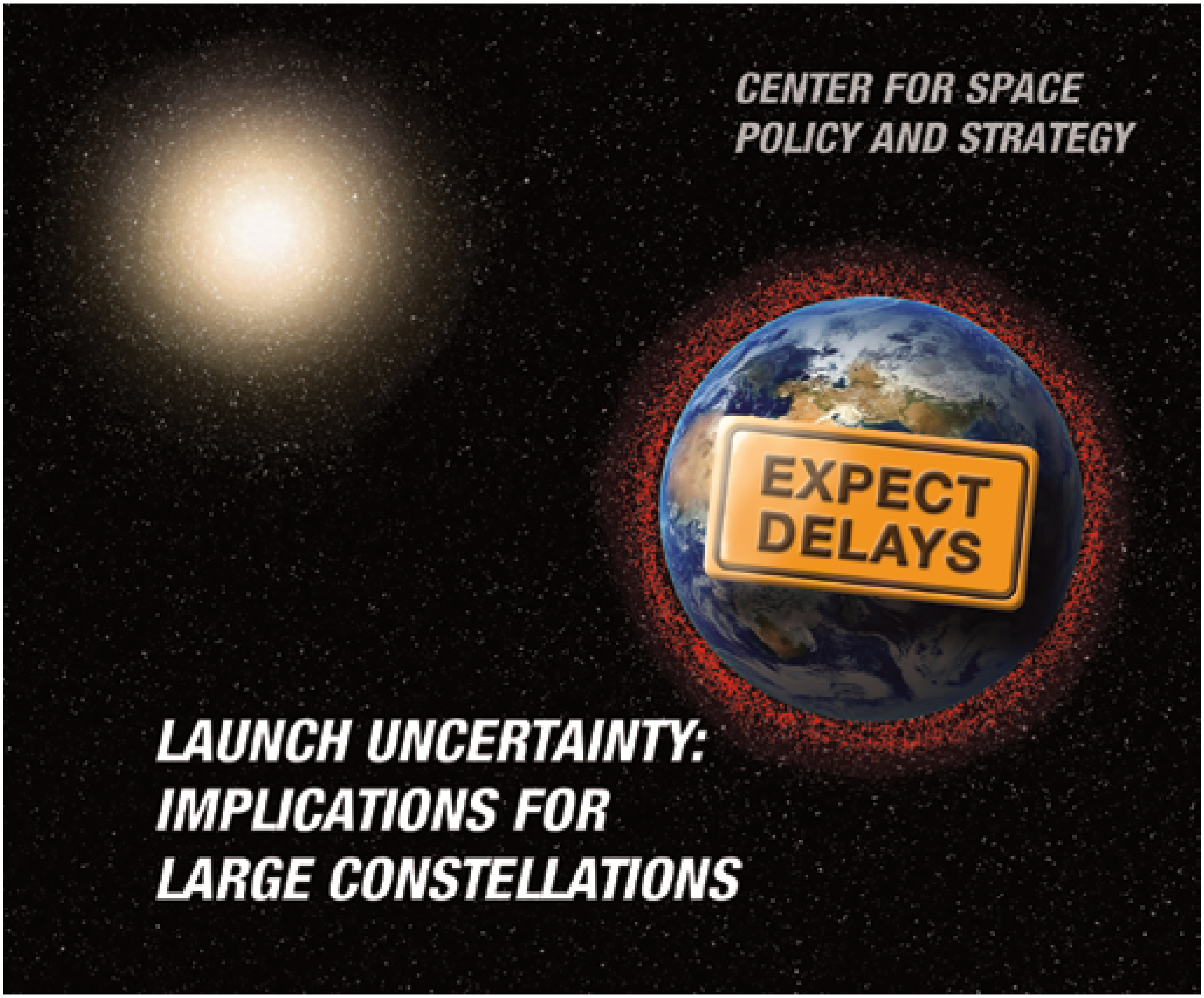
Launch Uncertainties

An AGI Analysis

By Grant R. Cates, Daniel X. Houston, Douglas G. Conley, and Karen L. Jones, The Aerospace Corporation



Constellations consisting of tens, hundreds, and even thousands of satellites in *non-geostationary orbits* (NGSO), sometimes referred to as mega-constellations, are now being proposed and developed to bring affordable broadband internet and other satellite services to the world. Hundreds of launches may be required to deploy and maintain these satellites.

Even after successfully navigating through rounds of investor funding and regulatory approvals, launch capacity and delays pose a significant risk to constellations, their stakeholders, and policymakers because the constellations must be deployed within a defined period, and failure to do so has onerous consequences.

This article defines the magnitude of the NGSO constellation challenge in terms of number of satellites proposed, regulatory deployment requirements, the uncertainty in future launch demand, and the inevitability of launch delays. Sources and consequences of launch delays are identified, and risk management and simulation tools are described.

Far-Reaching Consequences

The possibility of a high launch demand and the cumulative effects of launch delay risks could result in far-reaching consequences for U.S. launch service providers, constellation developers, and other stakeholders.

The evolutionary stages of the proposal, approval, deployment, and sustainment of NGSO constellations should be followed closely to discern launch demand and delay risks for individual constellations and at a macro-level for the launch service and NGSO constellation markets.

Quantitative assessments can shed light on the probability of satellite services availability and the potential for future market imbalances such as shortages of launch vehicles and spaceport capacity limitations.

Stakeholders, armed with launch demand and risk assessments, will be better positioned to adjust business strategies, capture needed investments, adjust government budgets, and effect changes in regulatory policies. It is both prudent and practical for stakeholders and investors to forecast launch demand and manage delay risks that threaten mission success and investment returns.

The Constellations

Private industry has proposed approximately 20,000 satellites for deployment into non- geostationary orbits, as shown in *Table 1* below, with approximately 13,000 having been approved by the *Federal Communications Commission* (FCC) thus far (*while there might be other constellations in addition to those listed below, the table represents U.S. license requests*).

Three companies — **OneWeb**, **SpaceX** and **Boeing** — are proposing constellations comprising thousands of satellites to provide global broadband internet access and other companies are proposing smaller constellations.

Table 1: NGSO Satellites—FCC Filings (2016 to Present)

Proposer	Proposed Satellites	Satellite Design Life (Years)	Orbital Inclinations (Deg.)	FCC Application Date	FCC Filing Number	FCC Approval Date	Approved Satellites
OneWeb LEO	720	7	88	4/28/2016	SAT-LOI-20160428-00041	6/22/2017	720
	1,260	7	88	3/19/2018	Additional request due to deployment rules change.		
OneWeb MEO	1,280	10	45	3/1/2017	SAT-LOI-20170301-00031		
	1,280	10	45	1/4/2018	Additional request due to deployment rules change.		
SpaceX LEO	3,200	5 to 7	53, 54	11/15/2016	SAT-LOA-20161115-00118	3/29/2018	3,200
	1,225	5 to 7	70, 74, 81				1,225
SpaceX VLEO	7,518	5 to 7	42, 48, 53	3/1/2017	SAT-LOA-20170301-00027	11/15/2018	7,518
Boeing LEO	1,948	10	45, 55	6/22/2016	SAT-LOA-20160622-00058		
	1,008	10	88				
Boeing MEO	60	15	63	11/15/2016	SAT-LOA-20161115-00109		
Boeing LEO	132	10	54	3/1/2017	SAT-LOA-20170301-00028		
MEO	15	10	63				
SpaceNorway	2	15	63	11/15/2016	SAT-PDR-20161115-00111	11/3/2017	2
Telesat	45	10	37	11/15/2016	SAT-PDR-20161115-00108	11/3/2017	45
	72	10	99				72
LeoSat	84	10	99	11/15/2016	SAT-PDR-20161115-00112	11/5/2018	78
Viasat	24	20	87	11/15/2016	SAT-PDR-20161115-00120		
Karousel	12	15	63	11/15/2016	SAT-LOA-20161115-00113		
O3b	32	15	0	11/15/2016	SAT-AMD-20161115-00116	6/4/2018	32
	10	15	70		SAT-AMD-20171109-00154		10
Audacy	3	12	25	11/15/2016	SAT-LOA-20161115-00117	6/7/2018	3
Kepler	140	10	90	11/15/2016	SAT-PDR-20161115-00114	11/15/2018	140
Theia Holdings A	120	12	98, 99	11/15/2016	SAT-LOA-20161115-00121		
Astro Digital U.S.	30	15	98	5/8/2017	SAT-LOA-20170508-00071		
Total	20,220						13,045

Regulatory Fielding Requirements

The FCC oversees spectrum use by commercial satellites and has put in place regulations to prevent "warehousing" of spectrum and orbital slots.

Warehousing occurs when a developer with exclusive rights is unwilling or unable to deploy its satellites and thus hinders the availability of commercial space services to the public that competitors might be able to provide.[1] Time is of the essence for constellation developers, as the FCC requires that they deploy 50 percent of their satellites within six years of license approval and 100 percent within nine years.[†2] Satellites must be operational to be considered part of the count.

†The rules in place prior to 2017 required the entire constellation to be deployed within six years of being granted a license. Failing such, the grantees' entire authorization was voided.

Failure to meet either of these milestones results in the constellation being limited to the number of satellites already in operation on the milestone date. For example, a constellation planned for 100 satellites that has only 40 satellites in operation at the six-year milestone would have their FCC authorization reduced to 40 satellites. The licensee would need to request a license modification to deploy and operate additional satellites above that new limit and FCC approval would not be guaranteed.

Future Launch Demand

Future launch demand is driven by government and commercial plans to deploy satellites. The FCC, through its regulatory function of reviewing and approving NGSO constellations along with the attendant six and nine year deployment requirements, acts as a gatekeeper for launch demand.

The U.S. government uses multiple launch opportunities per year to meet various defense and civil missions. The burgeoning commercial Earth observation satellite industry is another source for future launch needs, with potential quantities in the thousands.[3] Commercial communications satellites destined for geosynchronous orbits will also continue to be launched each year.[4] Government decisionmakers need reliable aggregate launch forecasts to make timely and informed decisions.

Deployment Launches

Clearly, a large increase in launch rates would be required to deploy 20,000 satellites. Whether such an increase is even possible remains to be determined.

"*Some also question whether there are sufficient launch capabilities to get all of these [NGSO] satellites into orbit in time to meet the [six- year and nine-year deployment milestones]*," according to FCC commissioner ***Michael O'Rielly***.[5] Additionally, some financial and technology challenges remain to be overcome. Consequently, between unforeseen technology setbacks, potential mergers, acquisitions, bankruptcies, and market withdrawals, the number of satellites needing to be launched might be much less.

The number of launches required will be directly correlated to the number of satellites actually needing to be launched. To demonstrate the range of launches that might be needed, we considered multiple scenarios for the number of satellites needing to be deployed. These were 25, 50, 75, and 100 percent.

Trying to estimate the total number of launches required to deploy the proposed satellites is problematic because the FCC does not require license applicants to provide its launch plans. To develop reasonably accurate estimates, information on satellite mass and volume, anticipated failure rates, on-orbit spares plans, planned deployment schedules, planned launch vehicles, planned launch sites, and number of satellites that can be launched by any single launch vehicle is needed.

Aerospace developed a rough estimate for the total number of launches required for the deployment scenarios by taking into account publicly available information and making a few simple assumptions.

For example, at least one launch is required to populate an orbital plane. Fewer satellites can be launched when the intended orbit is highly inclined or is above Low Earth Orbit (LEO). We also considered historical information regarding the number of **Iridium *NEXT*** satellites (10) that are launched by a single ***Falcon 9*** and OneWeb's stated plans to launch as many as 36 satellites at a time on a Soyuz rocket.

We then assumed that the constellations are approved at the end of 2018 and that launches occur in time to meet the FCC deployment milestones with at least one year of margin. We further assumed that deployment launch rates will ramp up over the first few years such that the peak annual flight rate will not occur until approximately 2023. The resulting estimates for total launches required and peak annual launch rates are shown in *Table 2*.

Table 2: Total Launch Demand and Peak Annual Launch Rate Estimates

	Scenario			
	25%	50%	75%	100%
Total Launches Required	197	394	591	787
Peak Annual Launch Rate	32	64	96	128

Sustainment Launches — Design Life

In addition to planned launches to deploy the constellations, future launch rates also depend upon satellite design life. A useful satellite lifetime is the most significant factor in determining the required number of launches and frequency to sustain a constellation.

As shown in *Table 1*, SpaceX indicated that the design on orbit satellite lifetime will be five to seven years.[‡]

‡The Schedule S documents of both SAT-LOA-20161115-00118 and SAT-LOA-20170301-00027 state 5-year estimated lifetime of satellites from date of launch, but the verbiage in their respective Attachment A documents (technical information to supplement Schedule S) state, "Each satellite in the SpaceX System is designed for a useful lifetime of five to seven years."

Likewise, OneWeb has indicated a seven year design lifetime. Consequently, SpaceX and OneWeb may need to begin launching replacement satellites prior to the FCC's nine-year milestone.

Using the information from *Table 1* regarding number of satellites and design life, and assuming a six-year design life for SpaceX satellites, the estimated number of sustainment launches are shown in *Table 3*.

Table 3: Annual Estimates for Sustainment Launches

	Scenario			
	25%	50%	75%	100%
Annual Launch Rate	26	51	77	102

Achieved satellite lifetimes may be longer than planned lifetimes. For example, a study of military and civil satellites having various orbits (*Geostationary Earth Orbit* [GEO], *Highly Elliptical Orbit* [HEO], *Medium Earth Orbit* [MEO] and LEO) found that the average mission's actual life exceeds its design life by 2.6 to 4.9 years.[6]

Such uncertainty has enormous implications for future launch demand. It is also worth noting that the 125 LEO satellites in that study had an average design lifetime of less than three years. Satellites in LEO typically require additional propellant for orbit maintenance compared to satellites operating in higher orbits. The *Very Low Earth Orbit* (VLEO) satellites will likely require even more fuel. Design tradeoffs between satellite launch mass and volume versus lifetime will have implications for both the number of deployment launches required and subsequent sustainment launches.

We assume that constellation satellite replacement cycles will be accomplished using medium to large launch vehicles capable of deploying multiple satellites at a time similar to the initial deployment approach. For example, **Iridium** upgraded its constellation to Iridium NEXT by launching up to 10 satellites at a time on Falcon 9s. This was planned well in advance and provided Iridium with a cost- effective way to deploy 75 satellites.

Sustainment Launches — Random Failures

Each satellite in a constellation has the potential for a random failure causing complete or partial loss of utility. While these types of failures can occur at any time during a satellite's useful life, commercial satellites have a higher failure rate during the first year on orbit, ranging from three to five percent, after which the likelihood of failure drops to less than one percent.[7,8]

On orbit failure risk can be addressed by having a small number of on-orbit spares in each orbital plane. However, a higher- than-anticipated failure rate would require more launches to complete deployment, and the deployment completion date could be delayed. Note that studies indicating a three-to-five percent first- year failure rate followed by a failure rate of less than one percent per year were based largely on satellites that were produced in low volumes and underwent rigorous testing. Consequently, these failure estimates may not be predictive for mass- produced satellites that do not undergo similar testing rigor.

The satellite mortality rate for each constellation will likely be an area of considerable uncertainty until that constellation has been fully deployed and operated for several years.

There is a wide range of estimates for the potential number of failed satellites needing to be replaced on an annual basis; again, depending upon the number of satellites actually deployed, the number of spares put on orbit during the initial deployment, and the actual failure rate. *Table 4* provides projections for future annual small launcher demand, discounting availability of on-orbit spares, and assuming failed satellites are replaced on an individual basis.

Table 4: Annual Launch Demand Estimates for Small Launchers

	Scenario			
	25%	50%	75%	100%
1% Annual Failure Rate	50	100	151	201
3% Annual Failure Rate	151	301	452	602
5% Annual Failure Rate	251	502	753	1,004

Satellite failure rates and the potential need to replace individual failed satellites on short notice could create an ideal market for small launchers, including existing systems like the European ***Vega***, as well as several under development or now entering service such as **Rocket Lab**'s ***Electron*** and **Firefly**'s ***Alpha*** rocket. Air launched vehicles such as **Northrop Grumman**'s ***Pegasus*** and **Virgin Orbit**'s ***LauncherOne*** may be particularly well suited for individual satellite replacements, as they are able to launch satellites into a wide range of orbital inclinations due to their launch location flexibility, assuming that FAA's licensing facilitates such flexibility.[9] OneWeb has already put in place a contract arrangement with Virgin Orbit for 39 LauncherOne missions.[10]

Potential Launch Capacity Shortfall

The number of satellites in the proposed constellations and the FCC deployment milestones, creates the potential for a launch availability shortfall.

To quantify the magnitude of the potential shortfall during the deployment era only, we first estimated the present launch capacity for all medium and heavy launch vehicles likely to be used for the initial deployment of the NGSO satellites. We then considered how many non-NGSO launches are typically required on an annual basis.

The United States conducted 31 orbital launches in fiscal year 2018 using SpaceX, **United Launch Alliance** (ULA), and Northrop Grumman (NG) medium- to heavy-lift launch vehicles of the type that will be needed to perform constellation deployments.

SpaceX conducted 21 launches in fiscal year 2018 (FY18), which is a new record for them. In FY17, they launched 13. ULA conducted nine launches in FY18. In prior years, they launched as many as 12. NG conducted one orbital launch in FY18 and demonstrated up to two launches of ***Antares*** in prior fiscal years. Thus, the currently demonstrated combined SpaceX — ULA — NG orbital launch capacity is 35 launches per year.

Existing international launch vehicles such as ***Ariane 5***, ***H-IIA***, ***Proton***, and ***Soyuz*** are also likely candidates for deploying the constellations. The peak historical flight rates for these vehicles have been seven for Ariane 5, six for H-2, 12 for Proton, and 22 for Soyuz, for a total annual capability of approximately 45 launches. Launch vehicles from China and India might also be considered, but they remain constrained by U.S. restrictions on export of satellites containing U.S. technology.

Combining the present U.S. capability with the capabilities of the international launch vehicles cited above suggests a present capability of approximately 80 medium-to-heavy class launches per year. However, much of this capacity over the next 10 years may already be tasked.

The *Federal Aviation Administration* (FAA) estimates that the next 10 years will average 18 launches per year for large commercial geosynchronous satellites.[11] A total of 32 U.S. and foreign government launches were conducted during FY18 on a combination of Antares, Atlas 5, Delta II, Delta IV, Falcon 9, Soyuz, Proton, H-II, and Ariane 5.[12] Consequently, on the order of 50 launches per year seems a reasonable estimate for future launch demand before addressing the new constellations. Given a capacity for 80 launches per year and an existing need for 50 launches means that there are approximately 30 launches per year available for NGSO deployments.

Given an existing availability of 30 launches for NGSO constellation deployment, the potential capacity shortfall ranges from small to large as shown in *Table 5*. The results suggest that even if only a quarter of the NGSO plans come to fruition, current launch service providers will be tasked at maximum proven capacity.

Table 5: NGSO Constellation Deployment Launch Capacity Shortfall Estimates

	Scenario			
	25%	50%	75%	100%
Peak Annual NGSO Launch Rate	32	64	96	128
Estimated Current Availability	30	30	30	30
Potential Launch Capacity Shortfall	(2)	(34)	(66)	(98)

If the percentage of NGSO satellites needing to be deployed exceeds 25 percent, then the projected shortfalls indicated could become problematic (see *Table 5*). Such a market imbalance could lead to price increases, which could incentivize existing launch service providers to increase capacity and entice new launch service entrants.

Ramping up launch rates of existing vehicles will take time and considerable investment. For example, it took SpaceX eight years to increase its flight rate from 1 to 21 per year. It is worth noting that the past couple of years have seen a sharp increase, and the advent of the highly reusable Falcon 9 Block 5 may enable higher launch rates. However, recent comments from SpaceX suggest that FY19's launch rate will be on par with FY18 due to decreased launch demand.13 ULA took 12 years to increase its flight rate up to 12 per year.

New medium-heavy lift rockets are in various stages of development. U.S. vehicles include SpaceX's ***BFR***, ULA's ***Vulcan Centaur***, **Blue Origin**'s ***New Glenn***, and Northrop Grumman's ***OmegA***, the latter three of which were recently awarded development contracts from the U.S. Air Force.

Internationally, the *European Space Agency* (**ESA**) is developing ***Ariane 6*** as a replacement for Ariane 5 and the ***Japanese Aerospace Exploration Agency*** (**JAXA**) is developing the ***H3*** to replace the H-II. All are expected to have initial launch capability in the early 2020s. Given the historical record of how long it has taken to ramp up flight rates, these new vehicles cannot be counted upon to erase a potential 100-launch shortfall in 2023.

The fact that the shortfall is a projection with considerable uncertainty is particularly problematic for launch service providers developing new capabilities. This is because it is vitally important for providers to match their production capacity to launch demand to ensure profitability. See "*Launch Diseconomies of Scale*" later in this article.

Consequences of Launch Delays

When the FCC approves a proposed constellation, the race is on to meet the six-year and nine-year deployment milestones.

As proposers generally wish to have the FCC license in hand before too much investment is committed, the design of the constellation components — including the satellites and ground infrastructure — generally are not complete. Thus, the race includes design, development, securing capital funding, constellation deployment, and sustainment. As such, all delays during the time frame from license approval through the nine year, 100 percent deployment milestone are of interest as they lead to launch delays. Because constellation performance and viability depend heavily on the number of operational satellites in orbit, significant launch delays can be devastating.

Revenue and Profitability Impacts

Commercial constellation business plans should address the possibility that revenue will be delayed, potentially by years, and additional rounds of financing may be needed, as was the case with the Iridium NEXT constellation.[14]

Depending on deployment schedule margins and the extent of launch delays, profitability may be significantly reduced or never achieved, particularly in light of the federal regulations cited above.

Opportunities and Threats for Customers and Stakeholders

The advent of NGSO constellations creates new opportunities for customers and stakeholders alike.

Corporations, government agencies, health providers, academic institutions, and members of the public are keenly interested in taking advantage of the new services that the constellations will be offering. However, they will need to continue using their existing services until these new constellations come online. Some examples of opportunities and risks for stakeholders and other interested parties are described below.

Hosted Payloads

Even before the advent of large constellations, private industry advocated hosted payloads. "*We see hosted payloads as one of those inventive ways that the government can get dedicated capability in space without having to go and buy their own free- flying satellites*," said Intelsat President *Kay Sears*.[17]

The *Defense Advanced Research Projects Agency* (DARPA) is now funding an "*on orbit demonstration of a military missile warning constellation embedded within a commercial LEO mega-constellation.*"[18]

Government agencies and commercial entities planning to host payloads on constellation satellites may need backup plans to prevent capability gaps or insurance to mitigate revenue delays. For instance, **Aireon**, a company that has hosted payloads on the Iridium NEXT constellation, suffered from deferred revenue streams due to delays in the deployment of the host constellation.[19]

Launch Service Providers

Launch service providers will need to be able to launch the new NGSO constellations while continuing to launch critically important satellites for government agencies. They should be cautious, however, in preparing for a potential future increase in launch rates.

The increase may not happen as soon as planned and the overall level of increase may be less than anticipated. Should a constellation developer fail to meet an FCC milestone or otherwise suddenly cease launch operations, an immediate and precipitous decline in future launch demand could result.

The reality of this concern was amply illustrated in the late 1990s to early 2000s when the business failures of the Iridium, Globalstar, and Teledesic constellations caused a dramatic drop in projected launch service demand and prices, with corresponding financial challenges for launch providers.[20]

SpaceX is the only vertically integrated large constellation provider. SpaceX will build its own satellites and will use its own rockets to launch its broadband constellation. If there is a dearth of launch providers serving the NGSO market, access to launch capabilities through vertical integration could be a significant strategic advantage.

Spaceports and Launch Ranges

There are 11 commercial spaceports licensed by the FAA in the states of Alaska, California, Colorado, Florida, Oklahoma, New Mexico, and Virginia.[§,21] The Eastern and Western launch ranges, located at Cape Canaveral Air Force Station and Vandenberg Air Force Base, respectively, are managed by the United States Air Force and operated with the assistance of a fixed-price contract that has specified limits on the annual number of launches. An increase in launches above this level may require a commensurate increase in funding along with the hiring and training of new workers. Government officials advocating for new spaceports or managing existing spaceports and launch ranges will need to consider the long-term launch market outlook and whether they can "*close the business case*," for additional spaceport investments.

[§] Three of the eleven spaceports are colocated at government facilities: Spaceport Florida is colocated at Kennedy Space Center/Cape Canaveral Air Force Station; California Spaceport is colocated at Vandenberg Air Force Base; and Mid-Atlantic Regional Spaceport is colocated at NASA,Äôs Wallops Flight Facility in Virginia.

Geostationary Satellites

Orders for large geostationary satellites are down, with just eight orders placed in 2017.[22] This decline is largely attributed to satellite operators redirecting investment from traditional GEO satellite communications to NGSO constellations and the increased capacity offered by existing and planned high-throughput satellite (HTS) GEOs. If significant delays to the new constellations occur, or if their viability seems at risk, there could be a resurgence of orders for large geostationary satellites. The multi-year time frame from satellite order to availability of that satellite could also result in a service gap.

Orbital Debris Removal Services

A recent *SpaceNews* article addressing the need for orbital debris removal in the era of large constellations points out, "*The megaconstellations promising global broadband service are heightening concern about orbital debris and creating demand for space-based trash collection*," and cited several companies looking to provide active debris removal services.[23] Constellation deployment delays will postpone demand for such services. While delays provide additional time for removal capabilities to be proven, they also postpone the removal service providers' revenue streams and likewise threaten their viability. It is noteworthy that orbital debris service providers may become a source of future launch demand.

Launch Delay Risk Management

Risk management begins with gaining an understanding of potential launch delays and how they can impact constellation deployment milestones.

Historical data is analyzed to develop probabilities for individual launch delays and the duration of the delays. Simulation modeling is used to determine the cumulative effects of launch delays. If the potential impact is deemed to be problematic, then mitigation steps can be taken.

The proposed new constellations are not likely to impact launch availability for U.S. government programs with appropriate mitigation measures in place. These could include service level agreements with the launch providers and evoking government purpose priorities to mitigate launch delay risks stemming from the potential increased launch demand. Nonetheless, all launches are subject to delay risk.

Frequency and Sources of Delays

Launch delays remain a common theme across the space launch industry; "*launch delays are largely regarded as a condition of being in the launch industry.*"[24]

During the three-year period of calendar years 2015 to ì2017, 66 out of 71 U.S. launches were delayed, according to *Spaceflight Now*'s launch history log.[25] This database only captures delays that occur within approximately six months of the planned launch date, which is when *Spaceflight Now* typically starts tracking a launch. However, delays relative to a company's business plan can occur prior to that point. Delays range from a single day to years. Causes of delays vary, and we have grouped them into three categories: sourcing delays, launch site delays, and flight anomalies, as shown in *Figure 1* below. Additional details on each subcategory can be found in the appendix.

Figure 1. Launch delay risks.

Slip Charts

Causes of launch delays need to be accurately documented.

Peter Drucker's famous saying, "*If you can't measure it, you can't improve it*,' aptly applies. Slip charts provide an excellent method for documenting launch delay history. They portray the time when a delay occurs relative to the planned launch date and the magnitude of the delay, as shown in *Figure 2*. The planned launch date displays as a horizontal line so long as the launch date holds. A slip is displayed as a vertical step corresponding to the date the slip occurred and the magnitude of the slip, with a note describing the cause of the delay.

Analyzing the rich data in a collection of slip charts allows development of estimates for the likelihood of future delays, when and where they typically occur, and the potential magnitude of the delays.26 Launch service customers are well advised to request historical slip data from launch service providers to assess launch delay risk.

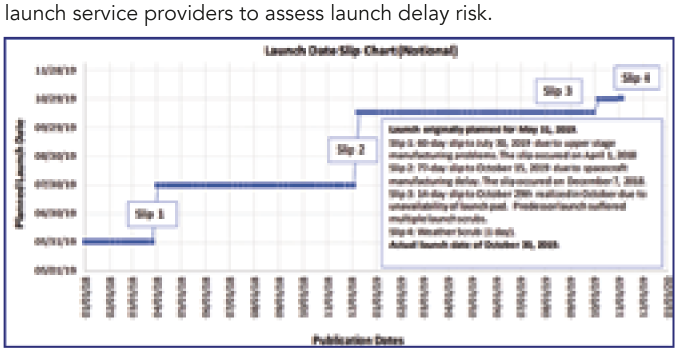


Figure 2. Example launch date slip chart.

We also propose a future launch rates working group, described later, to lead a study of delay risks across the launch industry. Such an effort could start by capturing and maintaining slip charts on all launch campaigns. Launch service providers, satellite manufacturers, and launch range officials could be encouraged to share launch delay historical data to firmly ground analyses and aid in the search for common causes and best mitigation practices.

Slip charts could also be used by the FCC to make better informed decisions when determining whether or not to grant waivers if and when deployment milestones are not achieved. If the collection of slip charts indicates that the preponderance of the delay reasons was beyond the reasonable control of the licensee, the granting of a waiver would likely be warranted. It is also important to establish up front how best to address when it is appropriate for the FCC to grant waivers in order to ensure a level playing field.

Simulation Modeling

Simulation modeling is widely used in operations research and for analyzing almost any system or operation, including manufacturing systems, transportation systems, and supply chains.

Discrete event simulation, similar to Monte Carlo analysis, models a system as it evolves over time and where system state variables change at discrete points in time.27 It is ideally suited for modeling a constellation's lifecycle from design, manufacturing, deployment, and sustainment. Entities within the simulation can include individual satellites and launch vehicles. Examples of state variable changes within the simulation would be the acts of completing a satellite's manufacturing, transporting it, and launching it into orbit. The occurrence of any launch delay risk (shown in *Figure 1*) would also be "discrete events," which contribute to whether any one constellation will meet its prescribed milestones.

Constellation stakeholders can refer to constellation simulations and the completion quantity distribution functions they provide, which show the number of spacecraft in operation as a function of time and, most importantly, how many satellites will be operational at the FCC's six- and nine-year milestones. *Figure 3* shows a notional constellation of 200 satellites with an FCC approval date of January 2018. The green line represents the planned number of satellites on orbit with the total constellation being deployed in five years per that plan. However, the simulation results with the model being run with either optimistic or pessimistic assumptions suggest otherwise. This notional analysis indicates that the satellite operator is at significant risk for not meeting FCC milestones despite a deployment plan that offers considerable schedule margin. The simulation would then be used to explore mitigation strategies that would improve the expected outcome.

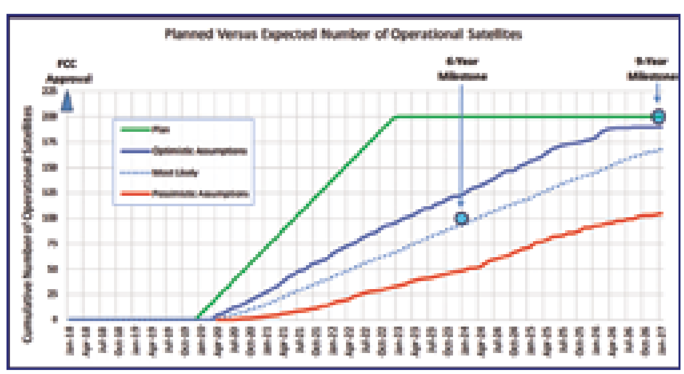


Figure 3. Notional 200 satellite constellation deployment analysis.

Launch service providers, constellation operators, and regulators should examine supply and demand models to better plan and predict launch availability or supply, launch demand, and resultant launch costs or pricing. A launch simulation output metric could be the expected number of launches, which launch service providers and launch ranges can use to better understand the possible number of launches required in the future. While a constellation developer would likely desire a simulation focused solely on a specific constellation, other stakeholders might be more interested in a model that considers all constellations along with other planned launches.

These launch models could also be used to predict future launch pricing by applying both launch supply and demand forecasts. Depending on the demand elasticity (price sensitivity) of certain NGSOs, such pricing models could be used to help forecast future business model changes or even failures. Launch cost is an important component of the overall satellite constellation. A study on the overall price elasticity of NGSO providers could shed light upon the market dynamics of NGSOs.

Simulations are most effective when they are based on historical data and in-depth knowledge of launch service providers, the launch operations infrastructure, satellite manufactures, current launch schedules, launch operations, launch ranges, satellite operations, and governing regulations. Included in such simulations are risk factors for delays throughout launch campaigns—from completion of satellite and launch vehicle manufacturing through each of their respective launches, as well as launch anomalies, satellite anomalies, and the uncertainty associated with satellite useful life.[28]

For example, a set of space shuttle launch date slip charts, coupled with simulation-based analysis, enabled accurate predictions for assembly of the International Space Station (ISS) after the space shuttle Columbia accident.[29] Launch delay data on multiple launch vehicles and corresponding models of the Eastern range launch infrastructure and workforce enabled accurate predictions for launch rates in 2016 and provided the Air Force millions of dollars in savings and cost avoidances.[30]

Policy Implications: The Government's Role as a Facilitator

Recent Policy Drivers

Governments are often the major drivers of space capability establishment and growth — for diversifying their economies as well as building strategic national capabilities.

To this end, the United States' *Space Policy Directive-2 (SPD-2*), "*Streamlining Regulations on Commercial Use of Space*," issued on May 24, 2018, encourages American leadership in space commerce and establishes space policy to promote economic growth and minimize uncertainty for both taxpayers and investors.

The directive calls for a review of regulations adopted by the U.S. Department of Transportation and consideration of:[31]

- *A single license for all types of commercial space flight launch and reentry operations*
- *Replacement of "prescriptive requirements" in the commercial space flight launch and re-entry licensing process with "performance based criteria."*
- *A review of export licensing reviews.*

The U.S. government could charter a working group to improve launch demand situational awareness for the benefit of all U.S. space launch stakeholders. Beyond streamlining regulations and establishing greater situational awareness of the launch market, the government may also want to consider other ways to nurture the domestic launch industry.

The U.S. government has already established a protectionist policy for the domestic launch industry by requiring that U.S. government payloads use U.S. launch vehicles. Going one step further (and not without controversy) the U.S. government could consider the circumstances where it would provide additional assistance to the NGSO constellations. If the U.S. government deems that assistance to NGSO constellations is in the national interest, it would need to determine what types of assistance are appropriate, potentially including regulatory relief, financial assistance, and even technical assistance.

For example, various government agencies and federally funded research and development centers could offer technical assistance. If some constellations are important to national interests, the U.S. government may want to consider a partnership whereby government funding is provided to the commercial sector for future services.

The *National Space Policy of 2010* encourages the use of public-private partnerships to meet the government's objective to promote a robust and competitive commercial space sector. By establishing a partnership, incentives are aligned for industry and government to share risk and work together. Both the Obama and Trump administrations have emphasized the importance of private investment when considering how to provide a public good such as critical infrastructure—an emphasis that extends to space.[32]

Facilitating Launch Demand Situational Awareness

Improving future launch demand situational awareness would be beneficial to multiple U.S. government entities and other spacefaring nations.

The Eastern and Western ranges, as well as other domestic launch sites, can use projections in preparing to meet future launch demand. The FCC can use launch demand estimates, along with launch capacity assessments, to better understand the likelihood of constellation license applicants being able to meet the FCC's six-year and nine-year deployment requirements. The Air Force can use the information to inform future acquisition strategies for their launch needs. Understanding the expected number of future launches is critical to making accurate predictions of future orbital debris risk. The *Department of Commerce* could apply launch demand projections as they work to ensure that the U.S. captures a sizable percentage of the launch market and to consider how to streamline regulations.

An inter-agency working group is recommended to bring together future launch demand information from the *FAA*, the *Department of Defense (DoD)*, *NASA*, the *FCC*, and private industry sources. With a charter to develop and maintain present and future launch demand situational awareness, this working group could develop an understanding of the U.S. launch market and worldwide launch demand.

The working group could develop estimates for planned future launch rates based on integrating information from a variety of existing products and sources, including:

- ◊ *Current Launch Schedule (CLS). The Air Force produces a product called the that extends approximately three years into the future and includes government and commercial launches from the Eastern and Western launch ranges. The CLS is the authoritative product for near term launch schedules.*
- ◊ *National Mission Model. The Air Force addresses government launches that extend another seven years beyond the CLS.*

◊ *Annual Compendium. The FAA provides information about commercial space transportation, including estimates for commercial launches over the next 10 years.*

◊ *International Space Station (ISS) Flight Plan. NASA maintains a flight plan showing U.S. and partner nation launches to the ISS.*

◊ *Commercial Sources. Several commercial sources could provide information on future launch demand such as SeraData's SpaceTrak, the* ***Teal Group****'s* ***World Wide Mission Model****, and* **Northern Sky Research (NSR)**.

◊ **Launch Service Provider Information**. *Information from launch service providers would be of value to the working group.*

The existing products, described above, do not currently identify the launches required to deploy the proposed constellations. Consequently, the working group would need to develop estimates for the number of additional launches required and when they are likely to be planned. The FCC license applications provide valuable information, but making future launch estimates requires additional information such as satellite launch mass and volume, anticipated failure rates, planned numbers of satellites per launch, intended launch vehicles, and launch schedules.

While one product of the working group would present the planned number of future launches as described above, a second product would be an analysis of the expected number of launches that will occur on an annual basis. This analysis could be accomplished through simulation based tool to account for launch range capacity, launch service provider capabilities, and launch delay risks. Understanding launch delay risks in particular is likely to be important to many stakeholders.

Facilitating NGSO Success Via Regulatory Relief and Rule Changes

Regulatory relief may ultimately prove to be necessary to ensure the success of the proposed NGSO constellations.

Indeed, regulatory relaxation has already occurred. The previous FCC rules required a constellation licensee to deploy the entire constellation within six years of being granted a license. Failure to do so would have rendered the entire authorization void.[33]

The FCC, anticipating unprecedented concepts for constellations of thousands of satellites, proposed alternative rules and sought public comment in 2015. The FCC proposed relaxing the constellation deployment time requirement and reducing the penalty for not meeting the deployment requirement. Only 75 percent of the constellation would have to be completed within six years, with the remainder needing to be deployed within nine years. Failure to meet the milestones would result in the constellation being limited to the number of satellites operating at the time of the milestone.[34]

Many companies provided comments to the FCC. OneWeb, having already been granted a license to deploy 720 satellites, urged the commission to retain the 100 percent completion milestone to deter speculation. Boeing proposed that the full deployment milestone be increased to 12 years. SpaceX suggested that there be no set time requirement for deployment.[35]

When the FCC announced the rule change, each commissioner provided a statement for the record. Commissioner O'Rielly's statement may prove to be particularly prophetic:

> *"Ultimately, we may need to see how these systems develop and how many come to fruition and, based on the actual systems deployed, rule tweaks may be necessary. I think we all know that twelve NGSO systems – and this does not include the V-band constellations – are unlikely. For the time being, we have done our best to provide the necessary framework and environment for investment."*[36]

Rule changes can have significant consequences. For example, after the FCC announced the change in 2017, OneWeb petitioned the FCC on March 19, 2018, to be allowed to increase the size of its constellation from 720 to 1,260. In a nod to constellation deployment delay risks, OneWeb stated that they had based the 720 number "*on the basis of a milestone regime that required launch and operation of the entire constellation within a six-year time frame.*" They went on to state, "*If the current milestone regime [50 percent in six years, 100 percent in nine years] had been in effect when OneWeb began planning its constellation and network architecture, OneWeb would have proposed a much more expansive LEO Constellation.*"[37]

Changing a rule, granting a waiver, or approving a license modification may be perceived as unfairly assisting a licensee to the detriment of competitors. Rather than waiting several years, the FCC and other regulatory parties, working closely with the satellite industry, could start meeting on a regular basis to develop ground rules to allow for greater future regulatory flexibility while maintaining fairness among the competing parties. This might serve to reduce both regulatory burden and industry angst. Such actions would be consistent with the administration's efforts to make space regulations less burdensome and to encourage U.S. space industry growth and competitiveness.

Conclusions

Large NGSO satellite constellations will play a strong role in closing the digital divide, demonstrating U.S. commercial leadership in space, and providing unique satellite service opportunities for government and private sector customers.

Yet, there is no guarantee that these constellations will make it from the drawing board to reality. Their arrival depends upon many factors, including technical viability, availability of financing, ramping up U.S. launch capacity, and the herculean efforts required to produce, launch, and maintain unprecedented numbers of satellites. Launch delay risks will be pervasive throughout, and the cumulative impact of launch delays to large constellations will likely be measured in years.

Some risks may be mitigated via the addition of launch processing infrastructure, increased workforces, judicious use of overtime, ample schedule margin, and potentially regulatory relief. However, even with such mitigations in place, a significant level of delay risk will remain.

That risk should be thoroughly analyzed, constantly monitored, and communicated to the NGSO stakeholders as well as the government agencies that rely upon timely satellite launches to meet their mission needs.

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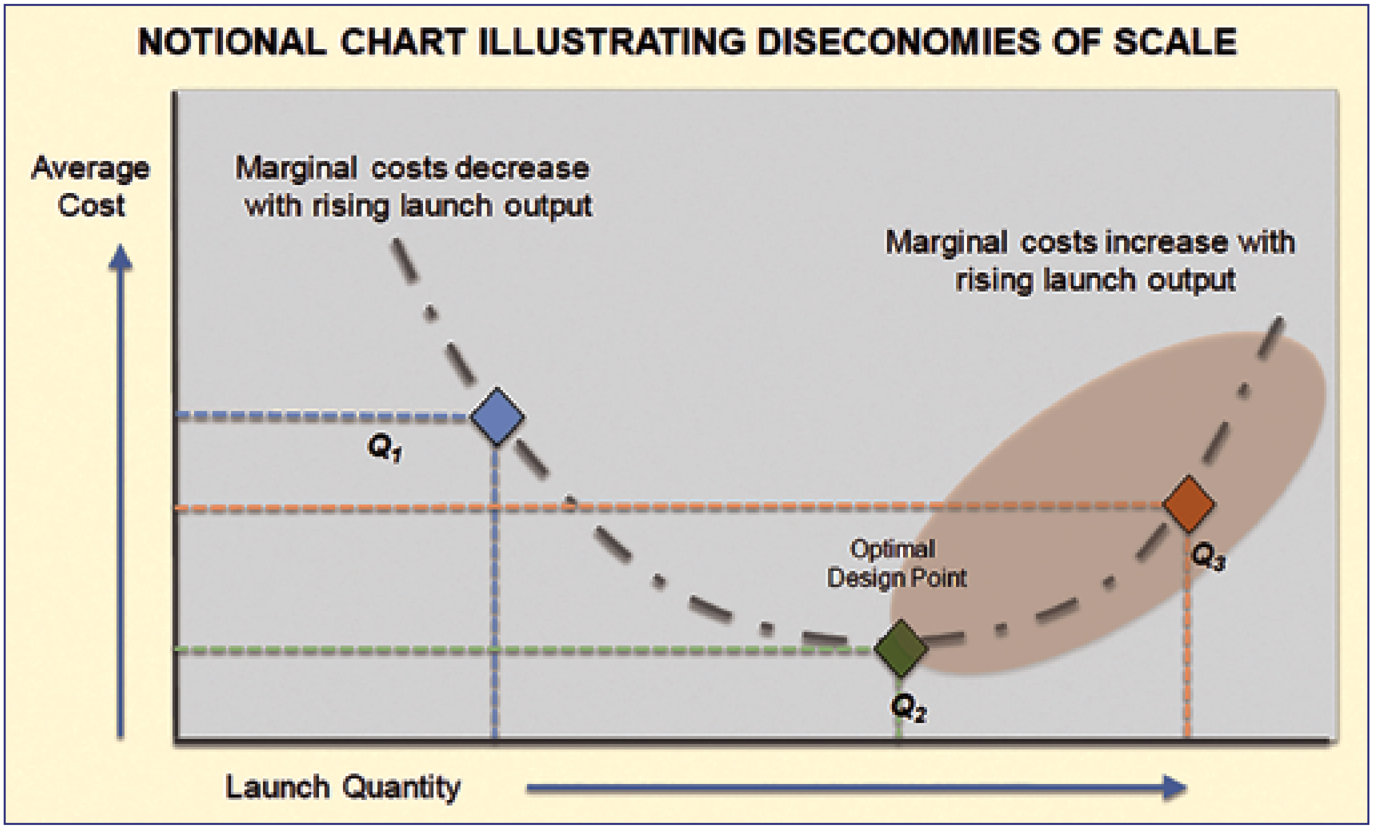
Launch Diseconomies of Scale

The microeconomic principle of ***economies of scale*** refers to reduced costs per unit that arise from increased total output of a product. For instance, a launch provider could provide an increased quantity of launches and spread launch site infrastructure costs and general technical and operational support costs across all launches; thus, reducing the costs per individual launch.

Diseconomies of scale might occur after output quantity exceeds an optimal design point. It remains to be seen where such a diseconomy will occur for the launch industry as no historical precedent exists. There are, however, potential scenarios where ***diseconomy*** might occur for an unprecedented level of space launches. Why is this significant? Marginal cost increases could increase launch prices over time, dampening future launch demand.



Diseconomies of scale may result from several factors such as:

- ◊ *Increasing launches may pose a challenge to the current channels of communication between constellation operators, regulatory authorities, and launch providers. Beyond a certain threshold, it is possible that further investment and staffing will be required to meet increased launch demand*
- ◊ *Launch providers may not be prepared to be responsive beyond a certain threshold. enhancing a launch provider's ability may incur demand for additional staff*
- ◊ *Launch sites may need additional capital improvements to stage and launch frequent launches.*

Diseconomies may extend further up the space value chain to satellite manufacturers. Northern Sky Research noted that while LEO constellations theoretically benefit from economies of scale, the satellite industry is quite modest in size, compared to other industries that clearly benefit from mass production economies of scale (*e.g.*, the automotive industry).[15] OneWeb plans to produce 15 satellites per week from its Florida-based facility.[16] If OneWeb and other LEO satellite manufacturers manage to produce as expected, they must still rely upon the launch industry to place their satellites in orbit. The key questions are:

- *At what satellite manufacturing volume level would satellite manufacturers reach the optimal design point?*
- *At what launch volume level would a launch provider reach the optimal design point?*
- *If diseconomies occur, how long would this scenario last before the industry adjusts supply capacity to meet these new unprecedented levels for satellites and launch services?*

All market participants and regulators should watch closely to observe any adverse trends.

Appendix: Causes of Launch Delays

Sourcing Delays

Satellite Availability

The design, development, manufacture, and test timeline of a satellite is a complex endeavor, typically requiring years and often taking longer (sometimes much longer) than planned. The first new satellites for constellations are exposed to such delay risks. Once design and production processes mature, delay risks typically diminish but are not eliminated. Delays are quite possible, given that providing satellite-based global Internet services is a relatively new technology.

For example, on May 1, 2018, OneWeb announced that its first 10 operational satellites, previously planned for launch that month, had slipped to the end of the year.38

Ground System Availability

The ground system required for the orbiting satellite constellation is also a source of delay risk. A recent example is the delay to deployment of GPS III satellites due to delays in completing the GPS III ground system.[39,40]

Launch Vehicle Availability

Like satellites, the development and production of launch vehicles can also lead to delays. The likelihood of a delay and the magnitude of the delay are both typically greatest for the maiden launch. Launch vehicle production can be impacted by natural disasters near or at the production facilities.

Metrics on annual flight rates by launch service providers, both domestic and international, for the past several years show that any given provider has a relatively stable flight rate to meet its existing demand. These providers' production lines are based upon the expected launch rate and will take time to ramp up.

The addition of hundreds of launches to propel thousands of satellites into orbit over the next several years seems likely to intensify delays due to a potential lack of launch vehicle availability. It is also possible that the price of launch services will increase if demand significantly exceeds supply.

Transportation

Accidents and delays happen in all modes of transportation. During the space shuttle era, a train carrying solid rocket motor segments from Utah to Florida derailed and an external tank being barged from New Orleans to Cape Canaveral was nearly lost at sea during a tropical storm.[41]

The Delta Mariner, a ship designed for carrying rockets from Alabama to Florida, collided with a bridge while proceeding in the wrong river channel at night. Satellites are also at risk. For example, damage during shipment of Superbird 8/DNS 1 to its launch site caused a nearly two-year delay.[42]

Regulatory

The licensing process for launch vehicles and satellites can result in launch delays. The Secretary of Commerce has stated that the current process for gaining regulatory approvals can take longer than the design-to-launch process. The National Space Council and the U.S. Department of Commerce are working to streamline the regulatory process to mitigate future delay risk.[43]

Launching on foreign soil does not free U.S. satellite operators from U.S. regulatory oversight and the delays that might result from such oversight and review. After a satellite is separated from their launch vehicle, satellite operators must adhere to the policies of their country of origin or registration, not the country from which they are launched.[44]

Launch Site Delays

Launch Vehicle and Satellite Processing

Activities during launch processing campaigns for both the launch vehicle and spacecraft can be delayed for any number of reasons. Individual tasks may take longer than planned. Problems or accidents during processing may occur. An issue with flight hardware may be discovered prompting a recall.[45]

Delays can occur when transferring flight hardware elements from one processing site to another (e.g., from an integration facility to a launch pad) due to weather or other causes. Labor disputes may result in the processing workforce going on strike or social unrest in the local area may cause a halt in operations.[46,47]

Launch Provider Capacity

The limited capacity of launch site processing infrastructure contributes to delay risk. Integration facilities may only be able to handle serial processing of one rocket at a time.

The facilities' processing capacity limitations consequently become production bottlenecks to higher launch rates and limit a launch service provider's ability to catch up after a delay. Likewise, all launch pads can handle only one rocket at a time and require several days after a launch for refurbishment before they can accommodate the next launch.

A related launch provider capacity limitation stems from environmental concerns. Providers are required by the *National Environmental Policy Act* (NEPA) of 1969, *42 United States Code* (U.S.C.) *§§4321–4347* (as amended) to conduct environmental assessments to determine potential harm to the environment and public from their launch operations.

These assessments are based, in part, on a maximum number of launches per year specified by the proposing launch service provider. The SpaceX environmental assessment for SLC-40 at Cape Canaveral Air Force Station (CCAFS) specifies 12 flights per year.[48]

Kennedy Space Center's LC-39 consists of two launch pads (39A for SpaceX Falcon launches and 39B for NASA's SLS) allowing up to two launches per month and up to 24 launches per year, but these numbers include non-SpaceX launches as well.[49]

At Vandenberg Air Force Base (VAFB) in California, the SpaceX assessment for SLC-4E cites 10 launches per year.[50] The yet-to-be-built SpaceX launch complex in Texas cites 12 launches per year.[51] The environmental assessment for Blue Origin's New Glenn rocket allows 12 launches per year at CCAFS.[52]

The limits specified in these assessments may become a source of delay to constellation deployment. However, the government enforcement mechanism for these cited maximum launch rates is unclear. NEPA is subject to a citizen suit provision, meaning anyone can bring a lawsuit against the responsible federal agency for alleged NEPA violations.[53]

Current U.S. environmental assessments for rocket launch operations do not require consideration of atmospheric effects of rocket exhaust emissions above 3,000 feet. However, concerns regarding such emissions coupled with a large increase in launch rate could prompt new regulations and specify additional limits on launch frequency, further delaying constellation deployments.

Scientists are beginning to explore this concern and the ***United Nations 2018 Quadrennial Global Ozone Assessment*** will include a section focused on rocket emissions.[54] "*The relatively unconstrained atmospheric flight operations enjoyed by space launch providers since the beginning of the space age cannot be taken for granted as a permanent condition.*"[55]

Range Availability

Launch ranges have limitations in their ability to conduct large numbers of launches. The Eastern and Western ranges can conduct only one launch on any given day and require a day or two between launches to reset. As ranges become congested with multiple launches, delays can accumulate.

A launch service provider is typically allowed a couple of launch attempts before having to yield the range to another waiting user, with the delayed launch moving to the next available time slot on the range. After being scrubbed for weather three days in a row, the STS-101 mission was delayed nearly three weeks because Atlas and Delta launches were scheduled for the next two weeks.

The advent of autonomous flight safety systems (AFSS), capable of terminating flight if a rocket malfunctions, is changing this constraint. While only SpaceX is flying such a system today, the Air Force is pressing all U.S. launch service providers to implement AFSS. However, conducting same-day launches may still be problematic because rockets with AFSS use GPS signals, which become disrupted by rocket exhaust plumes.[56,57]

The separation in time between launches from the same site will need to be sufficient to allow GPS distortions to dissipate, which is analogous to spacing aircraft far enough apart to avoid accidents from shedding vortices. Other considerations include proximity to adjacent launch pads that preclude same-day launch operations or hazardous operations such as static fire testing.

Other factors can hinder the conduct of launch operations on ranges, including workforce limitations and natural disasters. The range operations workforce for CCAFS and VAFB is sized for the expected number of launches and resizing this workforce for a significant increase in launches takes time.

Hurricanes, wildfires, and earthquakes may also disrupt operations. A large wildfire in California, for instance, scrubbed an Atlas V launch countdown and caused major damage to the range infrastructure. Launches were halted for seven weeks.

Launch Scrubs

Because launch pads can accommodate only one launch vehicle at a time, launch scrubs contribute to limiting the overall launch throughput. Launch scrubs are exceedingly common and occur for a variety of reasons. The probability of a launch scrub varies somewhat between providers based upon vehicle design, launch commit criteria, and local weather.

The time to the next launch attempt after a launch scrub depends on the reason for the scrub. In the case of scrubs for weather, the next attempt can occur on the following day. However, launch scrubs due to flight hardware problems often require a longer time to resolve.[58,59]

Flight Anomalies

Launch Failures

When rockets fail to place their payload correctly into orbit, a subsequent extensive failure investigation determines the root cause, and corrective action is then taken to prevent a reoccurrence. During the investigation and corrective action period, which may be weeks, months, or years, the entire launch vehicle family is usually grounded.

While rare, ascent anomalies can occur on or very near the ground, and the resulting damage to the launch pad can be extensive. Therefore, the availability of that site for future launches depends on the amount of time needed for repairs.

The probability of a launch anomaly resulting in a grounding varies among launch vehicles, with some vehicles being perhaps more reliable than others based on their flight history. However, it is unreasonable to assume that any launch vehicle is immune to ascent anomalies.

Satellite Failures

If satellites being deployed fail on orbit, constellation developers may elect to halt deployment until the underlying problem can be determined and corrected. For example, Europe's initial batch of Galileo satellites experienced problems with their onboard atomic clocks after being placed in orbit. The Galileo managers elected to reschedule an August 2017 launch to December of that year and resolve the problem.[60,61]

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A Pivotal Time for the U.S. SmallSat Industries

A SmallSat Alliance Perspective

By Steve Nixon, President

Years from now, space historians will reminisce that this era was a watershed moment within the global competition for the development of space and the success or failure of subsequent business endeavors.

There are important challenges and missions with ongoing moon exploration as well as with rockets. However, future historians might look back at this time as the key moment that the United States either fully embraced and moved out aggressively on the disruptive technology of smallsats, or ceded this technology to global competitors such as China. These implications are profound for the nations and allied space economies and national security.

This year, many smallsat industry players will demonstrate important capabilities to their investors, partners and customers. Companies such as **Capella** (radar imagery), **Audacy** (communications), **OneWeb** (communications), and **Hawkeye 360** (RF geolocation) and others will test their prototype systems on orbit.

Launch companies such as **Virgin Orbit** and **Vector** will test their first orbital vehicles and **Rocket Labs** will demonstrate sustained commercial operations.

Many new companies will enter the smallsat market, while others will exit. All the while, investors will continue to evaluate company performance and make further investments into the companies that best locate customers and execute successful business plans.

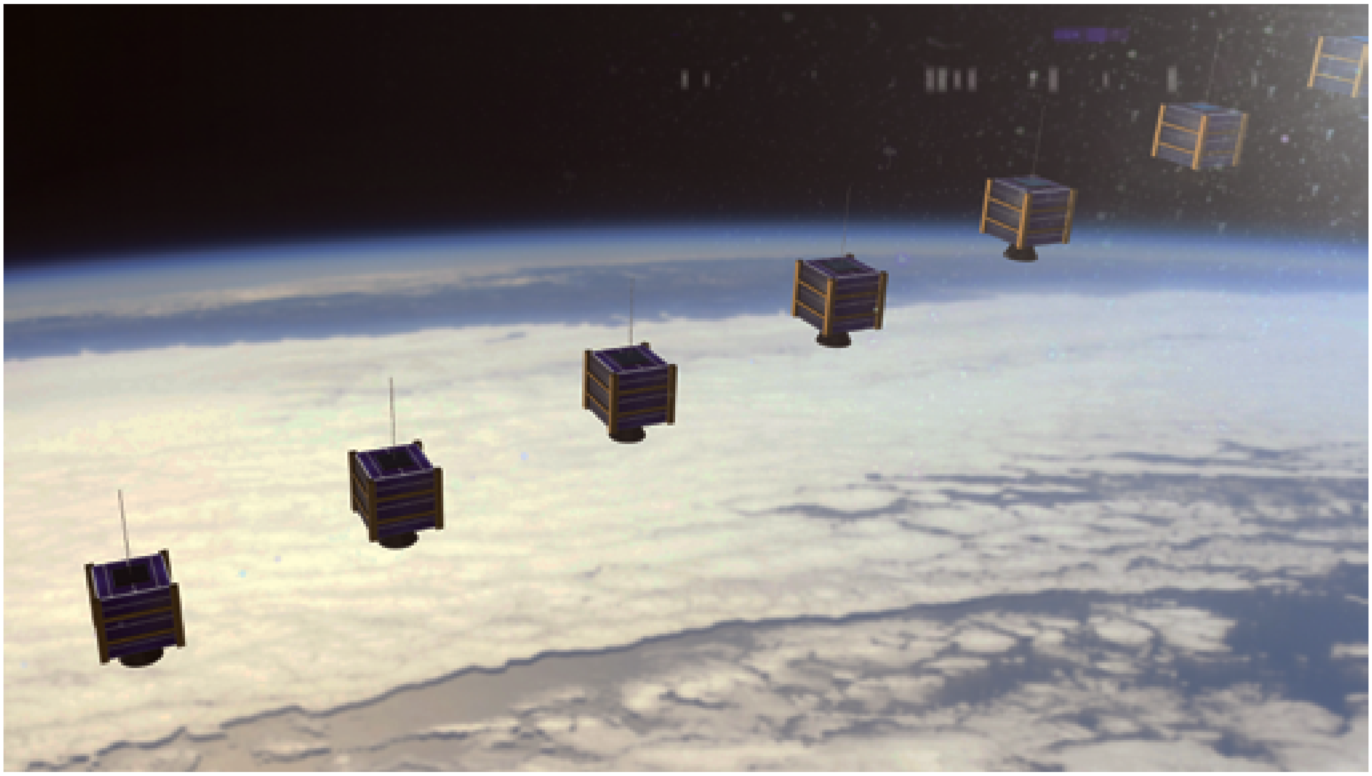
However, the biggest variable for the United States smallsat market is how the U.S. Government (SG) will participate.

The USG is, by far, the largest customer in the world of space capabilities, with the **Department of Defense** (DoD), the U.S. Intelligence Community, **NASA**, and **NOAA** the dominant players. These agencies have achieved countless, amazing feats in space and remain the preeminent global space organizations.

Unfortunately, they have — so far — taken a "hands off" approach to the commercial smallsat industry and that could jeopardize the success of this industry in the face of the ever-growing and intense global smallsat competition.

Most U.S. commercial smallsat companies in the last few years have started out with the intent to serve commercial customers, either exclusively or nearly exclusively. However, these companies quickly find that the USG is a crucial actor within the overall space market and to ignore their presence is unwise, to say the least.

The USG has huge, unmet needs, large budgets as well as large numbers of customers who are already familiar with space derived products. Commercial markets are still being developed and nurtured and few doubt the potential for amazing, commercial smallsat applications.



The U.S. National Security Space community desperately needs smallsats to improve resilience, deterrence, revisit rates, and innovation cycle times. The current legacy architecture, based on small numbers of large super-satellites, is powerful and effective and makes sense as long as no adversary has the means to attack those platforms.

Unfortunately, multiple countries have already demonstrated the capabilities that promise to hold space assets at risk. Virtually all of the U.S. National Security Space leadership acknowledges the need for proliferated architectures; however, so far, the smallsat investment has been less than one percent of the National Security Space budget. Important to note is that smallsats will not replace their larger kin. Rather, a new balance of capabilities is required, with additional use of smallsats to supplement the traditional reliance on larger satellites.

NASA's ***Science Mission Directorate***, to its credit, announced a major smallsat initiative late last year, planning a new $100 million per year investment. This commitment pre-dated the highly successful use of smallsats in a first-ever deep space mission — when ***InSight*** landed on Mars, two ***MarCO*** CubeSats were there to relay the telemetry back to Earth.

This success is creating additional smallsat interest within NASA. Hopefully, that will lead to additional missions. Ironically, budget pressures from sending humans deeper into space could be a further boon for NASA smallsats.

NASA's science and Earth Observation (EO) missions consistently poll high with Americans and the inherent affordability of smallsats might allow an expansion of science missions, even with constrained science budgets. (*In any smallsat strategy, NASA should encourage the agency's performing centers to partner with the emerging smallsat industry to help reduce costs while preserving excellent science.*)

NOAA also could benefit from smallsats and many companies, such as **Spire**, are stepping up to provide more ubiquitous, smallsat weather data collection. Unfortunately, these companies face cultural resistance within NOAA along with challenging contracting procedures that make it difficult for the agency to easily reach small commercial companies.

NOAA would benefit from a broader use of the so-called *Other Transaction Authority* for the commercial-like contracting that is available to other space agencies. Congress should address this problem to help NOAA and the commercial smallsat industry better work together. If the USG does not aggressively engage the commercial smallsat industry, and if the new smallsat companies can't survive in the short term with the nascent commercial demand, then we will surely cede this capability to other more aggressive countries.

Though many countries have strong smallsat industries, (*the UK and Russia, for example*), the most significant competition is coming from China. China is matching the U.S. smallsat industry move-for-move and in many cases faster and with more money.

The U.S. and Chinese commercial smallsat industries are chasing the same international customers, particularly in the Middle East and Asia. If China is able to move at a faster pace and is able to gain a secure foothold earlier, then the U.S. industry could be starved of important customers — smallsat disruptive technologies dominance will shift to overseas actors.

This dire forecast need not occur, and won't if the USG becomes a better customer and user of smallsat capabilities. The national security community should increase smallsat funding 10 fold, with NASA and NOAA committing to U.S. smallsat commercial technologies.

Given the relatively modest levels of current funding, this would not be a radical rebalancing of existing budget priorities. These monetary considerations are absolutely necessary to ensure the U.S. maintains leadership in science, to protect national security and to enhance the economic security of the nation.

Steve Nixon is President of the SmallSat Alliance. He is a former space industry executive and strategic consultant. Before that, he worked in the U.S. Government as Director of Science and Technology and Chief Technology Officer of the U.S. Intelligence Community. There, he spearheaded creation of IARPA, the Intelligence Community's version of DARPA. He was also a long time Professional Staff Member for the House Appropriations Committee as well as a Pentagon analyst.

SATCOM Goes Prime... Why Amazon's Entry Is Good for the Industry

An ATLAS Space Operations Perspective

By Mike Carey, Founder and Chief Strategy Officer

In late 2018, Amazon shook up the entire satellite communications industry when the company announced their partnership with defense industry veteran Lockheed Martin to create the new AWS Ground Station Service. The company's goal is to install 12 antenna ground stations all across the globe, which will connect customers with satellites through ground antennas.

As many SATCOM industry vets know, Amazon isn't the first to try this out — four years ago, I founded **ATLAS Space Operations**, a satellite data communications company that now counts tech behemoth Amazon as a primary competitor. Now that the corporate giant has entered this previously niche industry, you might think I'd be a little nervous of their presence.

However, the opposite is true — I'm not jealous at all. To me, it's clear: Amazon's entrance into the industry will open doors for us in a big way and drive innovation to entirely new levels.

When well-established companies such as Amazon and Lockheed Martin turn their attention to a new market, those moves validate every other company already working in that space and such can eventually help simplify the licensing and regulatory processes and operations.

Currently, ATLAS Space Operations is an intrepid pioneer that ventured into the Wild West of SATCOM; with Amazon and Lockheed Martin entering the industry and opening up new possibilities, the company might soon be considered the fearless leader who founded the segment and caused everyone else to eagerly to come with us.

That said, Amazon is bound to face several hurdles and Jeff Bezos and company should be prepared to overcome challenges such as:

Modulated data

Amazon is, more or less, replicating ATLAS' approach to data processing, but I'm not certain how they will address the custom handling of modulated data.

Each antenna frequency has a modulation being broadcast. It's similar to a radio, which has to be tuned to the frequency modulation or amplitude modulation to hear a certain station. No one company can put up an antenna for a specific frequency and cover everyone's needs; each customer has different requirements.

Not only is the multitude of modulation schemes somewhat challenging, but there also is a host of regulatory mazes that must be navigated to gain global access. To date, this has been unattainable on a large scale.

Transmission to spacecraft

To be able to transmit to spacecraft, a license is required for every spacecraft to which you transmit. The *International Telecommunications Union* (ITU) has regulatory governance over all satellite transmissions, and each country has

Map showing global deployments of ATLAS and Amazon ground stations.

authority over satellite transmissions within their physical domain — this makes it necessary to go wade through an army of regulators to obtain this crucial licensing.

Some countries are extremely challenging when it comes to obtaining licensing within — while Amazon is stating the firm can place antennas everywhere, they won't be able to control spacecraft as readily; the regulatory issue is challenging worldwide.

Additionally, the power required to be transmitted from spacecraft so it can be "heard" from a ground station is highly variable between spacecraft. Either the spacecraft has to be physically close enough to the antenna for the antenna to "hear" it, or a transmitter is needed with enough wattage to transmit in order for that antenna to retrieve the signal. That's called the link budget — the "listening" power of receiving antenna and transmit power of sending antenna to create a handshake.

If someone puts up 1,000 antennas and states everyone can use them, that assumes everyone has the same transmit threshold; however, that's not true. Each satellite behaves differently and a common ground station does not solve that.

The standards for modulations

Generally speaking, everything in the space community has been custom-built — spacecraft and their radio frequency modulation structures have been constructed with an almost artisanal, craftsman-like approach, so that one can squeeze every bit of data-carrying energy out of a transmission. This complicates the infrastructure and makes it expensive.

In order to make it less expensive, there has to be standardization among users or spacecraft operators; otherwise, each ground station has to be able to handle every custom-built spacecraft. Our software solutions and APIs are making inroads toward solving that issue. However, to scale quickly and effectively across the globe, satellite designers must agree with agreed-upon standards in order for Amazon to leverage their extensive infrastructure; otherwise, Amazon will be slaves to its own antennas, which will be expensive and unsustainable.

The scheduling

Amazon's announcement mentioned being able to schedule antenna access time, and that surprised us a bit, because that's an outdated concept.

In fact, I experienced the frustration that satellite control scheduling has caused during my 35-plus years in the U.S. Air Force. Competition for scarce antenna resources created issues whenever more than one operator needed access, because that meant prioritizing one transmission over another — something no mission-critical endeavor should ever have to deal with.

In the future, we believe you won't need to schedule your SATCOM data access, just like you don't need to schedule with your cellphone service provider the times you're able to make a phone call. Our vision is to create a satellite communications network similar to a mobile network; just as a mobile phone doesn't care what tower it's on, a satellite operator shouldn't care what country or geographic region it's flying over.

ATLAS Links, an electronically steered, lightweight and easily deployable array ideal for high volume or operationally limited environments. Links weighs only 55 pounds and can be carried in a backpack.

The antenna

Existing ground-based communications technology uses standard satellite dish-shaped antennas that must be aimed at the distant signal source. Weak signals need large dishes, which are expensive and unwieldy to move and set up. Large dish antennas usually are installed permanently at a single location; have limited windows of opportunity to communicate with orbiting satellites; and can only downlink data from one satellite at a time.

ATLAS still uses, and will continue to use, the traditional parabolic dish in our global network, but also has begun exploring new technology.

The company's ***ATLAS Links***™ systems (*see image above*) are small, portable mobile structures with four antenna units that constantly survey the sky for spacecraft signals. They use an array of antennas, massive computing power and algorithms that can isolate even weak signals. They can be set up and taken down within minutes, only require access to internet and power and can receive data from multiple satellites simultaneously.

Instead of using one "big ear," ATLAS has figured out how to use many "little ears" and this potentially quadruples the ability to download data from a traditional antenna. As the need for data increases, the company is working on creating a solution that changes the game in terms of moving to the cloud (in fact, we use AWS as our backbone) as well as advances the options for available hardware.

At ATLAS Space Operations, the firm is looking forward to this modern-era Space Race wherein Amazon and Lockheed Martin now find themselves — in fact, we're excited to share an industry with a company that drives innovation with such fierce creativity.

The entire world will be watching to see how Amazon navigates these challenges and we're hopeful that having them in the SATCOM space will help knock down some barriers we've already encountered, accelerate solutions to those problems, and move the needle even further in this important global enterprise.

https://www.atlasground.com/

Mike Carey is the Founder and Chief Strategy Officer for ATLAS Space Operations, which provides satellite communications as a service. Carey can be reached at ***mcarey@ATLASground.com***.

SmallSat Technology Democratizes Space...

An Axelspace Perspective

By Yuya Nakamura, President and Chief Executive Officer

The smallsats defined as CubeSats are now enjoying a golden age in the NewSpace industry; however, the smallsats that are considered microsats that weigh in around 100 kg. are on the rise because of their viable balance between high performance and low cost.

Nowadays, we see quite a few NewSpace startups coming into the industry with various business ideas using CubeSats. Most of them aim for optical Earth Observation (EO) or narrow-band communication business as they require a somewhat simple technology in order to fit into such a tiny spacecraft volume. This volume limit sometimes imposes a big constraint on payloads onboard.

Of course, CubeSats should be used if a mission is achievable with that technology and is also viable in terms of business. If that is not the case, however, a compromise must be made on something (perhaps data quality or capacity) to forcibly create smaller payload smaller that can be installed within a CubeSat. Microsats, with the mass of 100 kg., can untie such restrictions. In many cases, it is highly feasible to miniaturize a complex mission payload for accommodation by a microsat.

Who's Axelspace?

Axelspace is a Tokyo-based microsat startup that was founded in 2008 and aims for the practical utilization of microsat technology. The company vision is "Space within Your Reach," where the company drastically lowers the hurdles to utilize space through cost reduction and fast delivery for non-space private companies as well as the public sector.

Figure 1. Axelspace Team Members.

The founders of Axelspace are from the **University of Tokyo** and **Tokyo Institute of Technology**. While at school, they engaged in several smallsat projects that included the world's first successful CubeSat that was launched in 2003. Based on that experience, they decided to start the company in order to disseminate the value of smallsats to society. Currently the company fields 66 team members and one-third of them are from other countries. Axelspace enjoys an international atmosphere, which is uncommon for a Japanese firm.

The Company's Track Record

Axelspace has developed five satellites since inception...

WNISAT-1

Client: *Weathernews, Inc.*
Mission: Monitoring ice distribution in the Arctic Ocean
Mass and Dimensions: 10 kg., 270x270x270mm
Launch: November 23, 2013, by Dnepr, from Yasny Cosmodrome (Russia)

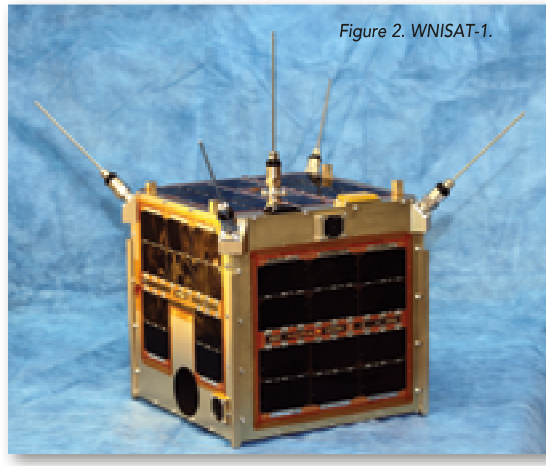


Figure 2. WNISAT-1.

Weathernews is the world's largest weather information company, headquartered in Japan. Due to global climate change, Arctic sea ice has been receding rapidly one result of this occurrence is that new routes are being uncovered by shipping companies.

These companies needed a navigation service to uncover safe routes, as large icebergs were present in many of these waters. At first, Weathernews tried to use satellite imagery from existing satellites in order to provide such service to clients; however, it was soon determined to be too expensive.

Weathernews decided to develop their own satellite and Axelspace was contracted to build the WNISAT-1. There were few microsat component providers at that time. This meant that most of the components aboard WNISAT-1 had to be developed by Axelspace, which eventually contributed to the current capabilities of the company, although the launch required more time than expected to be completed.

Hodoyoshi-1

Client: *The University of Tokyo*
Mission: Business demonstration using microsat
Mass and Dimensions: 60 kg., 503x524x524mm
Launch: November 6, 2014, by Dnepr from Yasny Cosmodrome (Russia)
The University of Tokyo started the government-funded project, in which four microsats were developed. The main purpose of this project was to demonstrate business using microsats.

Figure 3. Hodoyoshi-1.

Axelspace joined as a project member and developed the first satellite. "*Hodoyoshi*" describes the project concept, but this Japanese word is difficult to translate. The meaning is similar to "*reasonably reliable,*" that is, an attempt to try to balance between cost and reliability.

Hodoyoshi-1 is an Earth Observation (EO) satellite and provides images with 6.7 meter ground resolution. Since launch, the smallsat has been capturing more than 4,000 images and that has successfully raised expectations of the microsat business among potential Japanese clients.

WNISAT-1R

Client: ***Weathernews, Inc***.
Mission: Monitoring ice distribution in the Arctic Ocean, volcanoes and typhoons

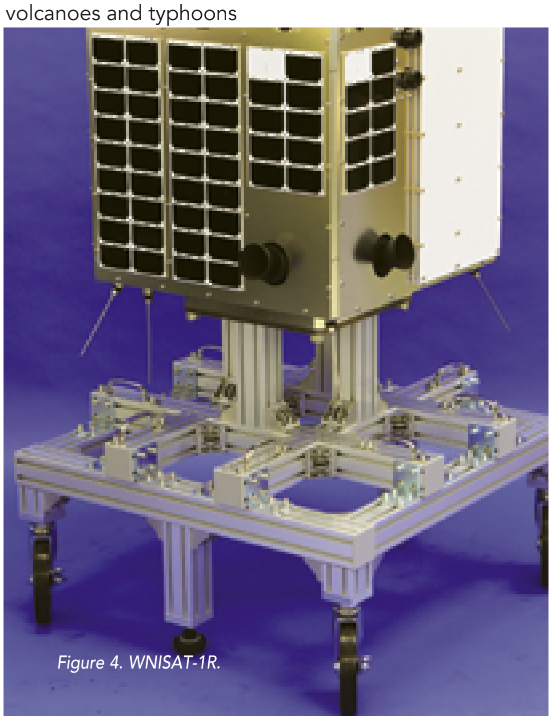


Figure 4. WNISAT-1R.

Mass and Dimensions: 43 kg., 524x52 x507mm
Launch: July 14, 2017, by Soyuz from Baikonur Cosmodrome (Kazakhstan)
WNISAT-1R is the second private satellite for Weathernews. This spacecraft is bigger than the original smallsat in order to accommodate more sensors. The main purpose of this microsat remained the monitoring of the Arctic area and volcanoes and typhoons were added to its monitoring target.

In addition, experimental instruments for GNSS reflectometry (***GNSS-R***) mission and optical communication mission are on board the satellite. GNSS-R is used to estimate the roughness of the Earth's surface, which can be applicable to the monitoring of ice distribution, even under an overcast condition.

GRUS

Mission: An entire world monitoring platform occurring on a daily basis
Mass and Dimensions: 100 kg., 600x600x800mm
Launch: December 27, 2018, by Soyuz from Vostochny Cosmodrome (Russia)
GRUS is the first satellite developed for Axelspace itself. Details to be described later in this article.

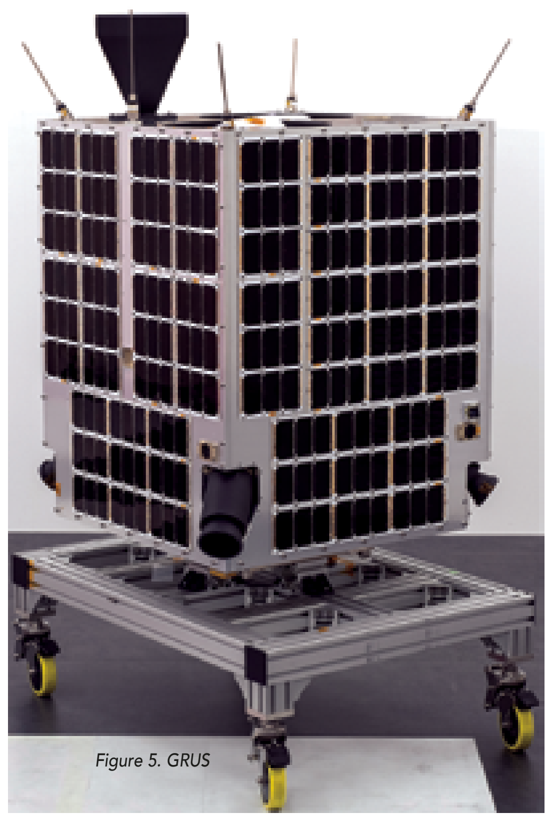


Figure 5. GRUS

RAPIS-1

Client: *Japan Aerospace Exploration Agency (JAXA)*
Mission: To provide a technology demonstration opportunity for private companies, research institutes and universities developing space instruments
Mass and Dimensions: 200 kg., 102x1082x1060mm

Launch: January 17, 2019, by Epsilon from Uchinoura Space Center (Japan)
JAXA designated Axelspace as the contractor of this

Figure 6. RAPIS-1. Image is courtesy of JAXA.

technology demonstration mission. Axelspace developed the satellite bus system to accommodate seven mission components selected by JAXA.

This was the first time JAXA contracted to a startup company, which made big news in the Japanese space industry. The spacecraft will be launched with other smallsats developed by universities and private companies.

As a 200 kg. class satellite, RAPIS-1 should probably be referred to as a "*minisat*" rather than a microsat. After this satellite's development, the satellite turned out to be a little too large to realize a reasonable cost. Axelspace is confident that microsats weighing up to 100 kg. can enjoy the best balance between cost and performance.

The satellites of Axelspace have been growing in size to pursue higher performance missions based on clients' needs. The company is able to develop a microsat at considerably lower cost because this vertically integrated company has nurtured original technology from scratch without the influences of conventional methods of satellite development. After being involved in JAXA's project, Axelspace learned new methodologies and achieved higher quality and reliability while avoiding any significant cost increases.

Significant Steps Forward

Readers may believe after reading the article so far that Axelspace is a "microsat manufacturer". Such was true until 2015, when the private satellite market was quite small. As a startup, Axelspace decided to start its own project to disseminate the value of microsats to the industry in a speedier and more efficient manner.

In November of 2015, the company garnered JPY1.9B ($17 million) in a Series A funding round — prior to that capital infusion, the company had operated without fundraising from venture capital. It was quite rare back then and this accomplishment became big news in the country. This successful fundraising contributed to various financing arrangements by other space startups throughout Japan. In December of 2018, Axelspace successfully closed their Series B round and secured JPY2.6B ($23 million).

As an aside, the investors of Axelspace include blue-chip firms such as Mitsui Fudosan Co., Ltd. (real estate), Mitsui & Co. (trading), Sky

Figure 7. Axelspace closed Series B funding round.

Perfect JSAT Corp. (satellite broadcasting and communication) and Weathernews Inc., in addition to venture capital firms.

Over recent years, non-space, large business enterprises in Japan have been paying more and more attention to the space business. They are rushing in to invest in promising space startups. The government of Japan has also been actively supporting space startups for a few years. For example, they established "***Space Industry Vision 2030***" in 2017 to nurture the space industry, with the goal of doubling its scale by 2030. They regard space startups as main players to realize such an ambitious goal and declared full-scale support.

Innovation Network Corporation of Japan (INCJ), a government-backed venture capital entity, is a lead investor for almost all space startups in their middle or later stages. Axelspace also accepted an investment of JPY0.6B ($5 million) from INCJ during its Series B round, although INCJ is not the lead investor.

The NexGen EO Platform

The project Axelspace is currently working on with these raised funds is *AxelGlobe*. As many as 50 microsats will be launched into Sun Synchronous Orbit (SSO), which will enable the firm to monitor the entire world on a daily basis.

GRUS is the satellite that will form this AxelGlobe constellation. The name GRUS is the Latin word for crane (bird) and the company's attempt is

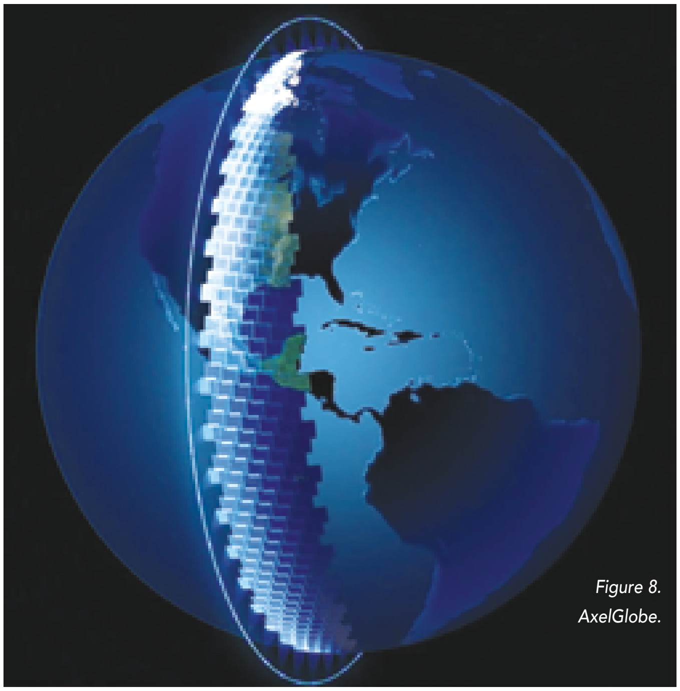


Figure 8. AxelGlobe.

identified using a scene of cranes flying in flocks. The ground resolution of GRUS images is 2.5 meters, which is called "*mid resolution*". The point to be emphasized is that this is *not* the technological limitation of a 100 kg. class satellite. GRUS does not pursue very high resolution, say better than 1 meter, on purpose. Instead, the satellite is equipped with two telescopes in order to realize a wide swath of 60 km. This is the reason why even a fleet with a relatively small number of satellites is able to achieve daily coverage of the whole world.

Many might believe that high-resolution images would result in greater revenues. In fact, the company notes there are more players entering this market segment with high-resolution imagery; however, there are fewer players with mid-resolution images than previously present.

Does this mean Axelspace should seek to offer high resolution images? There are several facts to be aware of before answering that question.

The first point, which is disappointing for a startup, is that the high-resolution market is already a "*red ocean*". The second point is that such high-resolution images are mainly for national security or military use. At least in Japan, the businesses dealing with high-resolution satellite imagery are restricted, to some extent, by government regulation.

How about selling data to non-military clients? Then the next question comes up — can the company compete with drones? After exhaustive consideration, Axelspace decided not to do so. The company should do what can be accomplished only from space, as the firm is spending enormous amounts of money launching satellites into orbit. Pursuing larger area coverage and higher monitoring frequency, while sacrificing ground resolution, seemed the best fit and that was the solution Axelspace reached. Covering the entire world on a daily basis is impossible for drones to accomplish.

Mass	100kg
Dimensions	600mm x 600mm x 800mm
Ground Resolution	Panchromatic: 2.5m, Multispectral: 5.0m
Spectral Bands	Panchromatic: 450nm – 900nm Blue: 450nm – 505nm Green: 515nm – 585nm Red: 620nm – 685nm Red Edge: 705nm – 745nm Near Infrared: 770nm – 900nm
Swath	> 57km
Life Span	> 5 years

Table 1. GRUS main specifications.

The table above shows the main specification of GRUS satellite. One important feature of AxelGlobe is that all GRUS satellites are to be placed in a single orbital plane. That allows the company to capture all of the images at approximately the same local time anywhere in the world and that will deliver the uniform sunlight condition across all images acquired from the constellation.

That is more important than perhaps expected, as the image analysis will be performed mainly by machines. Imagine — Axelspace compares two images acquired at the same location; one was captured at 9:00 a.m. on a certain day and the other image was taken at 4:00 p.m. on a different day. The direction of cast shadow must differ between two images.

It is easy for humans to understand that it is a meaningless difference in terms of extracting some business insights from this comparison. For machines, however, things are completely different. The machine needs to be "taught" in order to understand that this type of difference should be ignored, and that is highly inefficient. It is never realistic to analyze image data with the human hand because the data amount to be acquired annually from the constellation will reach as much as several petabytes when complete. Taking this into consideration, Axelspace's remote sensing experts and deep learning engineers are deeply involved in the development of the platform for data distribution and image analysis.

Data from the AxelGlobe constellation will grow in popularity across a wide range of industries as a unique data source. However, its use may not expand that much while the number of satellites on orbit is small and the data accumulation is not adequately robust.

Even so, AxelGlobe has received interest from governments and well-established companies around the world. An interesting application is attracting special attention from some potential clients among others: environmental monitoring. More and more companies are forced to prove they are not causing any damage to the surrounding environment. AxelGlobe can be the optimal solution, as the continual monitoring of large areas is required for such an application.

On December 27, 2018, the first GRUS satellite was launched by Soyuz. The satellite is in commissioning phase at the time of this writing. The delivery of imagery data is planned for the spring of 2019.

www.axelspace.com/en/

Yuya Nakamura is the President and CEO of Axelspace Corporation. He earned his doctoral degree in Aeronautics and Astronautics from the University of Tokyo in 2007. While in school, he engaged in three nanosat projects, including the world's first successful CubeSat launched in 2003. Yuya has also been serving as a member of the Committee on National Space Policy since 2015.

Achieving Large Scale Success With SmallSat Budgets + Constraints

A Braxton Technologies Focus

By Heidi Wright, Director of Technical Marketing

Smallsats. They are delivering affordable agility and flexibility for the space and satellite industry, but there are countless hurdles to overcome to be viable, long-lasting, and robust solutions to the problems that customized large and expensive systems face.

Indeed, the explosion of smallsats in recent years has inspired the minds of anyone who is even tangentially interested in the space domain and has brought into question the future of large spacecraft and their role both commercially and for governments.

With the increase in commercial launch platforms, space is more accessible today than ever before. Smallsats are not only a great entry point into space for countries, universities, and industry, but they offer an alternative solution that is cheaper, smaller, and more agile to continue achieving the mission on a shorter timeline than traditional missions.

To continue accelerating the smallsat revolution's positive trajectory while reducing the costs of putting satellites in space, the question quickly turns to "*what innovative, cost-effective, and high-quality solution does the smallsat market need to continue quickly delivering capability to those that need it*?"

One often overlooked answer is a flexible plug-and-play ground architecture that doesn't require immense investment from smallsat providers. Leveraging an existing infrastructure by offering a "*lease as you need*" model can avoid excessive ground costs from establishing an entirely new set up. A commercial facility operating satellites that isn't burdened by controlled access to a government facility can be the answer and one exists today at the Catalyst Campus.

The **Catalyst Campus for Technology & Innovation (*www.catalystcampus.com*)** is a collaborative ecosystem located in downtown Colorado Springs, Colorado, that harbors an impressive collection of industry, academia, and government entities with the purpose of promoting partnerships and leveraging commercial and government investments enhancing technology in the space arena.

Currently spanning over eight acres and 135,000+ square feet of commercial space (with an additional 50,000+ square feet planned in the next year), Catalyst Campus (***www.catalystcampus.com***) provides an infrastructure designed to support rapid development and innovation of technology that can immediately meet the needs and demands of smallsat developers and customers.

Braxton Technologies, LLC, is one of the flagship members of the Catalyst Campus. Braxton is an agile small business headquartered in Colorado Springs that specializes in developing software products to outfit any part of a satellite operations center.

Leveraging their satellite operations knowledge and location on the Campus, Braxton has created an environment where providers can fly their satellites, including smallsats, from a commercial facility for a small fraction of the standard, start-up ground system cost as the infrastructure, products, technology, and lab space already exist.

The infrastructure at this facility affords smallsats the opportunity to fly their spacecraft in an environment already compliant with the most common data and communication standard formats. Specific solutions are quickly tailored to meet specific needs and requirements.

Oftentimes, smallsats experience significant budgetary constraints, trying to squeeze as much value from a mission that they can with their limited resources. Frequently, there is not enough budget to consider a robust ground solution that isn't hobby-shopped together or only considered as an after-thought; most of a smallsat project's budget goes towards the satellite manufacturing and launch, where it rightfully should be.

Having an existing plug-and-play infrastructure for the ground control segment is of vital interest to the smallsat community, which removes a level of complexity from planning their mission and implementing the total solution. In addition to leveraging an existing, common infrastructure, another value-added component is the ability to lease the capability as needed, using a services model.

Many smallsat missions have a shorter life span and it therefore doesn't make sense to invest significant resources into developing a ground segment that will not be used for an extensive period of time. Braxton offers a ***Satellite Operations Center-as-a-Service*** (SOC-S) specifically for the smallsat community. This SOC-as-a-Service model gives users and operators the ability to manage constellation-level missions that leverage existing commercial products, therefore eliminating the need for further development, testing, and integration activities.

Smallsat missions frequently get bumped down the priority totem-pole for antenna time in favor of military missions and requirements. As part of the SOC-S concept, Braxton has formed valuable partnerships with commercial antenna providers to hook into commercial apertures of all sizes and at all latitudes to ensure resilient and secure global access to a satellite vehicle at any time while also enabling data routing consistent with mission requirements. Commercial antennas provide smallsat operators resilient access to their space assets and the opportunity to still receive their data and contact their satellite at desired points of time.

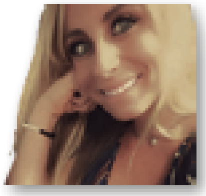
Braxton is scheduled to support several satellites from the Catalyst Campus in the next year and offers an extensive array of solutions that are easily tailored to meet smallsat ground needs; everything from satellite command and control, to constellation-level mission management, enterprise-level scheduling and resource optimization, satellite and ground simulations, and orbit determination — Braxton does it all for a fraction of the cost of traditional providers.

Please visit Braxton at Booth 16 at the ***Smallsat Symposium*,** February 4-7, 2019.

www.braxtontech.com

Heidi Wright is the Director of Technical Marketing at Braxton Technologies, LLC headquartered in Colorado Springs, Colorado. She specializes in combining her engineering and business development background from working at several small businesses and government agencies to market and deliver cost-effective, high-quality agile technical solutions for satellite ground systems. She holds a B.S. in Aerospace Engineering from Auburn University and is currently pursuing her MBA at University of Colorado at Colorado Springs.

LEO Satellite Ground Infrastructure Capital Reduction



A CM Technology Perspective

By Kailey Theroux, Chief Operating Officer

In the SATCOM world, most of the focus is on outer space; however, what occurs on the ground is just as important and can be challenging as every satellite, no matter how advanced, is still only a part of a larger system. Ground infrastructure is critical to providing the reliability people expect and is not something to be taken lightly.

Advances in technology and the response of the market is driving the SATCOM industry toward smallsats and, as that market continues to grow and transform the industry, various satellite companies are now preparing to launch large constellations of less expensive smallsats into Low Earth Orbit (LEO).

While this transition itself may be the "talk" of the industry, engineers and investors should consider how ground systems will evolve to support these rapidly growing constellations. Tracking LEO satellites is far more complex than for GEO satellites and requires many more gateway locations and antennas for global coverage.

LEO Tracking antennas have higher maintenance costs due to additional wear and tear that results from constant movement, as compared to a GEO tracking antenna platform.

While it is now less expensive to post a satellite into LEO than GEO (Geostationary Orbit), getting that data back to Earth is more difficult and expensive. LEO Satellite operators — large and small — can leverage significant reduction in capital expenditures by using the services of existing teleports that offer ***Lease Space Agreements*** (LSA), often through a LEO Teleport Services Company.

This includes companies such as **RBC Signals** which is working toward low cost ground solutions as alternatives to the purchase of high capital infrastructure. The company can offer turnkey management of data delivery for Network Operators while offering them affordability at the same time.

"*We are different from other providers in that we have developed a new model that enables efficient, cost effective data services to satellites in Low Earth Orbit*," said ***Christopher Richins***, Co-Founder and CEO of RBC Signals, in an interview with ***Newspace People***. "*We are currently the first and only provider utilizing the sharing economy model to reduce cost and improve service levels. Our global network leverages the excess capacity of existing ground station infrastructure to provide low cost, low latency communication services. This is important because many of the existing services are expensive and offer limited coverage for real-time communication.*"

Richins continued, *"The other alternative available to commercial satellite operators — developing their own new ground stations — is complex, expensive, and time consuming for operators. A number of the trends we are witnessing now will continue over the next five years. The industry is going to mature and expand the commercial viability of space-based information. The cost of launch services will be driven down and we hope that the reliability of launch vehicles will increase.*

"Also, because small satellites are affordable to build, the number of spacecraft in LEO for Earth observation and related functions will increase dramatically. Data will be king and will improve life on Earth: increasing health and safety, advancing environmental awareness and management, and creating efficiencies in business."

LEO satellites offer several advantages over their GEO cousins. Compared to a GEO unit, a LEO satellite has lower launch costs, reduced power requirements and a significantly reduced roundtrip transmission delay.

The popularity of LEO satellites is dramatically increasing. According to Professor ***Keith Willey*** of the **University of Sydney** in an article in *Microwave Journal*, "*The advent of constellations such as Iridium (66 satellites), Teledesic (228 satellites), Skybridge (80 satellites) and Globalstar (48 satellites) suggests that LEO constellations could become the basis of future two-way wireless communications systems. This possibility makes the tracking of LEO satellites an important issue for today's Earth station designer.*" While the costs of ground infrastructure remain high, there are alternatives available now and other solutions are underway.

LEO ground support service providers can now offer customized ***Service Level Agreements*** (SLA) to ensure that network design criteria is met, and reduces operational costs while improving performance. Managing LEO satellites on the ground requires advanced Network Management solutions that scale to support multiple sites and an integrated global network of tracking antenna. A network management "presence" can be offered within each teleport, along with backup ***Network Operations Centers*** (NOC).

An SLA contract should include NOC services with 24/7 monitoring and control over all network elements, including the satellites, ground sites and interconnections, service monitoring and performance analysis. The SLA contract should also include performance analyses for quality control purposes as well as orbit determination reports along with satellite and network engineering support. A LEO Teleport Services company assembles many teleports around the globe offering disparate services, together under a single SLA contract supporting a globally unified solution designed to support LEO networks.

If satellites are evolving, then ground stations must, as well, support them. The ground is just as important as outer space and more companies are now seeking partnerships with LEO Satellite Teleport Services companies and the belief is that mergers will certainly stem from the rising number of new entrants that are offering ground station services.

cmtleo.com

The Year(s) Of The SmallSat

A Firefly Aerospace Perspective

By Dr. Tom Markusic, Chief Executive Officer

2019 is the year of the smallsat. Of course, 2018 was also the year of the smallsat. As was 2017 and 2016. The most common occurrence in the smallsat business is that schedules always shift to the right. Historically, there are several reasons that contribute to this schedule shift.

Many of the companies pursuing smallsat applications are developing constellation strategies. These constellations consist of tens to thousands of satellites.

The development of technology demonstrators and of the full constellation requires substantial capital that is often difficult to raise. There was substantial movement on the financing front for constellation projects in 2018. Beyond some of the larger planned constellations such as **OneWeb** and **Starlink** that have previously announced funding, smaller constellations have announced successful deployment of demonstration satellites and capital raises.

Cloud Constellation Corporation capped off 2018 funding announcements with a $100 million capital raise for space-based data centers, showing there is an appetite in venture capital, not only for existing space based applications, but for the unique applications that have not yet been implemented. In all, closings of many hundreds of millions of dollars were announced for new Smallsat constellations in 2018 alone.

In additional to financing, the December 2018 **SpaceFlight's *SSO-A* SpaceX** mission could prove to be a pivotal milestone for the smallsat industry. Years of planning went into making that mission a success.

With more than 35 companies participating, including **Astro Digital**, **Astrocast**, **Audacy**, **Blacksky**, **Capella**, **Fleet Space**, **Hawkeye 360**, **ICEYE**, **Novawurks**, **Planet** and **Swarm**, many companies were able to prove out critical technologies, add to existing networks and, in some cases, trigger additional financing.

Beyond development of satellite technology, one of the primary concerns funding sources express to new entrants in the smallsat industry is that, aside from proving their technology, they must also show a path to space. A completely developed and manufactured smallsat sitting on a shelf does not generate revenue.

As most of the smallsat constellations being developed are in the under 300 kg. category, they are relegated to secondary payloads on large launch vehicles. Schedule and orbit are determined by the primary cargo and slips in the primary cargo schedule can have devastating effects on secondary payloads.

A company that raises money to launch a technology demonstrator where additional funding will be released after the technology is proven would be exposed to substantial risk is the primary payload falls six months to a year behind schedule, as often happens with large satellite development efforts.

Companies that have developing smallsat business cases must demonstrate access to economical, affordable launch services. As of last year, a **Northrop Grumman** survey indicated that there are more than 100 companies pursuing small launch options to service smallsats. Most of those companies will not make it to space, as the technical and financial hurdles that smallsat launchers must overcome provide a very high barrier to entry. Despite those barriers, it is expected that several smallsat launcher companies will soon be available to provide launch services to the burgeoning smallsat industry.

Rocket Lab successfully executed three launches in 2018. **Virgin Orbit** has indicated they are preparing for their first launch in early 2019 and several other companies, including **Firefly Aerospace**, have announced an intention for an initial launch in 2019. Once several of the proposed small launchers demonstrate consistent cadence at an economical price, additional smallsat business cases will begin to close and a rapid expansion of viable smallsat businesses will occur.

The Firefly Aerospace vehicle family is a primary path for this acceleration of the smallsat industry. The ***Firefly Alpha*** launch vehicle will accommodate 1000 kg. of payload to a 200 km. Low Earth Orbit (LEO) and 630 kg. of payload to a 500 km. Sun Synchronous Orbit (SSO). The SSO orbit is one the critical destinations for the smallsat industry and is currently underserved for dedicated launches.

Alpha is the largest American smallsat launch vehicle expected to be in service by the end of 2019 and no competing vehicles with a similar payload capacity are expected to be in service until at least 2021.

Surveys of potential customers have indicated the 1 metric ton capacity of the Alpha is in the "Goldilocks" range of dedicated smallsat launchers. It is large enough to deploy multiple 125 kg. class satellites so that planes of smallsat constellations can be easily deployed and small enough that aggregators can manifest entire vehicles consisting of combination of microsatellites and CubeSats.

The Firefly launch vehicle family will be expanded with the ***Firefly Beta*** by mid-2021. Beta is a four metric ton launch vehicle that will be the only "*Constellation Class*" smallsat launcher available domestically. Beta will directly compete with the *Indian Space Research Organisation (*ISRO*) PSLV* launch vehicle in both price and payload capacity.

The technology for the Beta will be heavily derived from flight heritage Alpha technology, using substantially the same engines, structures and avionics. This will allow for rapid development of the Beta vehicle once the Alpha successfully launches.

The Beta will also allow for missions beyond LEO. Firefly was recently selected by **NASA** as one of the nine companies that will compete to deliver payload to the surface of the moon.

NASA expects to spend over $2.6 billion dollars over the next decade on CLPS science missions. By providing an integrated offering that includes a launch vehicle and lunar lander, Firefly will allow companies that are developing lunar payloads schedule assurance and consistently available launch slots, which will rapidly accelerate the nascent small lunar science industry.

Firefly continues to show schedule credibility by consistently hitting major announced schedule milestone. Commencing stage qualification testing was one of Firefly's primary goals for 2018, which was successfully achieved.

The integrated stage testing includes flight-configuration propulsion, structures and tankage, pressurization and propellant management systems, and avionics. The stage operates autonomously, controlled by Firefly-developed flight software. These tests also demonstrated full activation of Firefly's large-scale vertical test stand, "*TS2,*" at Firefly's Briggs, Texas, test facility.

In 2019 Firefly will continue qualification testing of both the first and second stages of Alpha and begin flight acceptance testing in May, supporting the company's goal of a December 2019 first launch from Vandenberg Air Force Base Space Launch Complex 2-West.

fireflyspace.com

Prior to co–founding Firefly, Tom served in a variety of technical and leadership roles in new-space companies: Vice President of Propulsion at Virgin Galactic, Senior Systems Engineer at Blue Origin, Director of the Texas Test Site and Principal Propulsion Engineer at SpaceX. Prior to his new–space work, Tom was a civil servant at NASA and the USAF, where he worked as research scientist and propulsion engineer. He holds a Ph.D. in Mechanical and Aerospace Engineering from Princeton University.

PERFORMANCE	ALPHA, α	BETA, β	UNITS
Payload (SSO, 500km)	630	3,000	[kg]
Payload (LEO, 200km)	1,000	4,000	[kg]
Payload (GSO)	n/a	400	[kg]
ARCHITECTURE			
GLOW (SSO, 500km)	54,000	149,000	[kg]
Number of Stages	2	2	
Total Length	29	31	[m]
Max Diameter	2.00	2.80	[m]
Structure	All Composite	All Composite	
PROPULSION			
Oxidizer	LOX	LOX	
Fuel	RP-1	RP-1	
Max Thrust (stage 1)	736	2,208	[kN]
Max Thrust (stage 2)	70	163	[kN]

Figure 1. Firefly Vehicles Overview.

The World's Most Valuable Resource... Data

A GomSpace Perspective

Investments in smallsat driven missions and platforms continue to grow at a significant pace, as commercial, governments and academic markets recognize their advents and potential.

Technology is maturing and focus moves from prototype to industrial production. This opens up questions as to how data should be handled most efficiently and methods of how to exploit missions in best possible ways. In recent years, GomSpace has prepared for these new challenges, adapting to change in the different stages and phases; preparing for industrial production and now offering constellations management as a service.

GomSpace Products

GomSpace Flight Heritage and Core Competencies in RF

Through their ongoing in-orbit demonstration program "***GOMX***," GomSpace has demonstrated implementations of LEO satellites which has since been used in several commercial missions moving to provide new services based on the data obtained from these missions.

GOMX-1 in 2013:

- *Robust and reliable platform*
- *ADS-B based aircraft tracking*

GOMX-3 in 2015:

- *Agile ADCS performance includes target tracking*
- *Drag management*
- *3 SDR based payloads*
- *X-band downlink*

GOMX-4 in 2018:

- *Inter-satellite linking*
- *Stationkeeping with propulsion*
- *Multi-satellite operations*
- *3 SDR based payloads*
- *3 Optical payloads*

GomSpace is currently working with **ESA** on the ***GOMX-5*** satellite mission which is planned to be launched in 2021. GOMX-5 will demonstrate new nanosatellite capabilities for the next generation nanosatellites requiring high speed communications links and high levels of maneuverability.

Since the beginning, GomSpace has been developing cutting edge space technology especially within nanosatellite radio communication and advanced radio payloads. GomSpace possesses unique competencies within radio technology, advanced antennas and software defined radios as well as knowledge about radio-links in space. GomSpace is expanding its radio product platform for space-to-ground as well as space-to-space applications and will introduce new antennas and radios within the coming year.

GomSpace continue making partnerships on developing and maturing new technology. One of the long-standing partnerships are together with **Aalborg University** in Denmark where programs currently work to increase battery life of satellites as well as a project for the development of high gain antennas for small satellites.

Strategy and Product Development

Focus for GomSpace product roadmap and associated technology plan is to increase the number of applications supported by nanosatellites within radio communication constellations and global asset tracking.

In practice, this means a continuous increase of the technical performance of GomSpace satellites, *e.g.*, larger on-board computing power, larger data transmission rates, improved antenna technology and a design optimized towards reliability.

Industrialization of Space Technology

GomSpace has built the basis for industrial production of nanosatellites and is transforming the portfolio to industrial production.

During the last years, GomSpace has worked to standardize its products and solutions to provide the customers with both the ability to use predefined designs but also to benefit from the highly modular nanosatellite subsystems in GomSpace product line. Through this process, GomSpace can ensure not only a high production rate but also a high-quality level in the final solutions.

For commercial applications, it is key to understand the reliability of nanosatellites in Low Earth Orbit (LEO). To support this, GomSpace have developed platforms to support an operational life of five years. This is achieved and documented through GomSpace's test and qualification processes. The GomSpace test schemes are continuously refined and optimized to support reliable missions based on smallsats..

GomSpace Manufacturing

The strategical shift from prototype to industrial production has meant to GomSpace a significant investment in not least new organizational competencies but also expansion for and investment in new facilities and equipment.

The manufacturing facilities at GomSpace consist of:

- *Electronic production for manufacturing of modules and systems for customer deliveries and for Satellites to be produced at GomSpace*
- *A professional class 100.000 cleanroom allows integration of multiple flight satellites in parallel according to strict standards for clean room assembly*
- *State of the art AIV facility for manufacturing of satellites in larger series*
- *In addition, fully new build testing facilities were inaugurated in 2018. The test center offers facilities for all necessary environmental testing among others radiation testing as well as thermal, vacuum, helium leak and other required for professional satellite manufacturing*
- *In 2019, a 'new product Introduction' area will be included for a smooth and fast-running in of new products.*

All production is performed by certified electronic workers and certified Assembly, Integration and Verification (AIV) team. Production is performed in collaboration with quality certified ***Electronics Manufacturing Service*** (EMS) providers and with incoming inspection and unit tests performed by GomSpace.

Currently, GomSpace's manufacturing capability is being transformed from prototype assembly to simultaneously producing *In-orbit Demonstration* (IoD) satellites in series. In 2019, Gomspace will be producing several satellites in different IoD projects. In the years to follow, production capability will be further increased so, the company will be able to produce at a level of hundreds of satellites annually in these facilities of which the majority part will be constellation satellites.

Operations as a GomSpace Service

While satellites are getting smaller and cheaper, constellations are getting larger and more complex.

The cost reductions achieved by smallsats have enabled new business models, but few are actively trying to solve the complexity of managing the mega-constellations. The vast multi-disciplinary knowledge necessary to operate a large constellation is often underestimated and the required amount of staff remains comparable to traditional operators.

In 2018, GomSpace initiated activities in Luxembourg focusing on constellations management services. The company's team is addressing the need for intelligent, flexible and scalable operations for satellite constellations by introducing a new cloud platform and service model.

GomSpace is leveraging more than a decade of experience enabling satellite-based businesses to provide a cost-effective solution to our customers. Since the firm's start, the company has generated a wealth of intellectual property and experience of operating

subsystems, payloads, platforms, constellations, ground stations and end-to-end services. All of these are currently being consolidated in the company's ***Mega-Constellation Operations Platform***, to offer customers constellation management services that...

- *Reduces CAPEX, avoiding large upfront investments in tools, infrastructure and staff*
- *Grows with the business, using the same platform to manage from the first in orbit demonstration to complete production systems*
- *End-to-end integration, including satellites, terminals, ground station networks and end-to-end services all in a single platform. Only this way can you truly optimize globally and locally*
- *Brings flexibility to changing business needs, such as maximization of the mission lifespan, reduction of the overall costs, compliance with regulations, maximization of service performance, coverage, management of service quality service or disposal at the end-of-life*
- *Fully automated routine operations and highly automated contingency operations, providing hands-off and even lights-out operations, enabling our customers to focus on their business*
- *Fully managed services, including data processing and dissemination, service quality control, actively securing the entire chain with world-class latency and uptime performance.*

Constellation management of smallsats requires a wealth of disciplines, such as configuration management, security, network management, situational awareness, orbital dynamics, scheduling, automation, disaster recovery, simulations, radio-frequencies and regulations. GomSpace has the expertise and tools, both continuously being integrated in our platform, that is used by each mission since AIT (*Assembly, Integration and Testing*) and growing with the constellation.

GomSpace is pioneering true development and operations in the space industry with strategies recognized by web applications and lean manufacturers. In this manner, GomSpace customers' business remains agile, swiftly adjusting to dynamic market conditions and actively responding to threats and opportunities.

Such a level of reliability and flexibility is only possible with a multi-layered automation solution that compounds the operators experience to generate increasingly more complex operations while keeping the total cost of operations at a competitive level.

GomSpace Luxembourg is supporting a growing number of missions, integrating with the leading ground station network providers and every month releasing new features and capabilities to improve the company's operations.

www.gomspace.com

A Kratos Constellations Podcast Excerpt... SmallSats

A smallsat chat with Carolyn Belle, former NSR analyst, now Director, KSAT Lite USA

The Kratos Constellations podcast connects listeners to the innovators, entrepreneurs, policy makers and disruptors who are making and remaking today's satellite and space industries.

Carolyn Belle, former senior analyst at NSR and currently the Director, Business Development for **KSAT Lite USA**, provides insights on emerging new applications and how the smallsat industry is impacting the market. Carolyn built NSR's practice in smallsats. The original interview is edited for brevity and format.

— Listen to this and 40 other podcast interviews on Constellations —
www.kratoscomms.com/constellations-podcast-sm

John Gilroy for Constellations
Five Thousand. That's the magic number of smallsats reported as launching within the next decade. Is that correct?

Carolyn Belle (CB)
Actually, we now anticipate about 6,000 satellites launching toward 2027, which is expected to generate more than $25 billion of revenue for manufacturing and launch providers. With more smallsat capabilities and developments in the market, it's not a surprise that we're seeing this growth.

Constellations
What's the breakdown between government and commercial?

CB
It's very much a commercial market — about 70 percent from commercial providers. About 20 percent are from government or military entities around the world. Many government players are interested, and we've seen lots of military adoption as of late. We're seeing the opportunities smallsats can provide, the way they can work in tandem with larger more capable satellites. By including smallsats in the architecture, you get additional capabilities, a more robust set of assets in orbit.

Constellations
Government has traditionally driven space investment. How much is coming from Silicon Valley and will it continue?

CB
We see ongoing interest from Silicon Valley. It's still focused there, but we see a broader set of investors around the world. There's been rampant growth and investment the last few years, but we may be approaching a bit of a slowdown. As investors look at the early funded companies — the Planets, the Spires that were successful coming out — there's a bit of a wait to see how those perform, how much revenue they get back, and what the exit looks like before a fresh range of investment.

Constellations
How does the timeline for this industry impact the appetite for return?

CB
The space industry has traditionally been a very long timeline business, but with smallsats, the scale at which you can take something from design to testing to implementation is a much shorter period. That reduces the time for investor return.

Constellations
Many are optimistic about the planned constellations. Assuming one is successful, how will that affect the large satellite operators?

John Gilroy, the host of Kratos Constellations podcasts, interviewing Carolyn Belle, former senior analyst at NSR and currently the Director, Business Development for KSAT Lite USA. Photo is courtesy of Kratos.

CB
That depends on the application. If its smallsats for earth observation, that's a different potential impact than for communications, which is getting a lot of interest given it's the largest commercial segment. That is where the GEO operators are nervous. With the mega constellations in development – OneWeb, SpaceX, LeoSat, Telesat – they're nervous should one of those be successful.

Even though none are deployed yet, we've seen an impact where the GEO players are holding off on ordering replacement satellites. They're not sure how much of their market is going to be taken by one of these LEO players. But they're also getting more creative, taking a few more risks in orbit to provide a more robust set of capabilities that may be better able to compete with the smallsat players. So we're seeing hesitancy, but then creative ways to move ahead and still do well.

Constellations
Even with optimism, there will be winners and losers. Will Silicon Valley make the right bets? Is this a horse race that no one knows who to bet on?

CB
Absolutely. Some make more sense than others. We see investors making plays for a wide variety of applications. Some investing in hardware, some on the operators who want to put up a constellation. Not all will be successful. We'll see some failures. We already see some saturation where there are too many players going after the same thing. And, it's not just what market you go after. It's how you design your system, how much financing you have, how much R&D is needed, and regulatory factors. There are many challenges.

Constellations
What's the environmental impact of having 5-6,000 new satellites in space?

CB
People are certainly nervous. Responsibility will be on satellite operators to treat the spectrum environment carefully. Spectrum is a limited resource, so we have to think about interference from all these satellites. You also have to look at avoiding potential collisions in orbit. Space traffic management is really an issue.

Constellations
The cynic says 'there's going to be collisions, people are going to make mistakes.'

CB
Hopefully not. Operators are aware of that risk, and they're working to mitigate it as much as possible. One solution is propulsion. Not all smallsats right now are outfitted with propulsion, which limits their ability to respond in orbit to a potential collision with another satellite or with a piece of debris. That capability will help them to respond more quickly, potentially enabling both parties to respond rather than if there's only one with propulsion.

You also have growth in de-orbiting devices, so that as soon as the satellite is no longer operational, it can more quickly exit space rather than waiting for this 25-year rule of slow de-orbiting.

Constellations
What about some of the other smallsat markets, like satellite refueling, life extension, and salvage?

CB
Yes. We see a lot more diversity coming from smallsats than we had with large satellites to begin with. With smallsats, there's a huge variety of applications, services, and sets of data that players are looking to provide. Also this potential for smallsats to play a part in satellite servicing and robotic work in space.

Right now, the plans are for larger satellites to manipulate large GEO satellites in orbit. But we see some smallsat activity. Some university projects are looking to develop robotics from a small profile satellite to interact with others in orbit.

Constellations
It seems robotics in space would bring lots of different skill sets and people, from mechanical engineers and computer scientists to students?

CB
There's lots of interest from the student community. With smallsats, you can get hands-on experience while in university or even high school. Previously space was something that you didn't really touch until your first post-grad job. Now you can hold it, build it, and put something in space.

Constellations
In software, there's 'killer apps.' Anything on the horizon for smallsats?

CB
There are players looking to find that killer app and some who think they have. I'm of the opinion that there's no single killer app for smallsats. There's lots of different value that can be provided with today's capabilities and those in development.

Constellations
For example?

CB
Situational awareness, whether on the military side or civilian. Also IoT, tracking everything that's happening on earth. Imagery has been a leading application of the smallsats deployed, but we're seeing other types of earth observation being pursued too. Synthetic Aperture Radar is something that smallsats are looking to do, which has been a technical challenge.

People are looking to do many things with space. Collecting other types of atmospheric data, financial applications of using smallsats, leveraging the security of space, entertainment, and marketing. It's a question of how rapidly they can develop those markets, whether there's enough downstream potential, and building out the distribution network to tap into and convince those customers to use the service.

Constellations
You wrote that smallsats are simply another piece to the value creation puzzle.

CB
Yes, it's important to remember that the space industry is much broader than just the smallsat industry. We still have very viable capabilities provided by large satellites in GEO and LEO, and using those assets together can potentially provide more value than in isolation. Smallsats aren't the entire picture. You can potentially get a lot more value if you take a more cohesive approach.

Constellations
What are the options for getting smallsats in space besides the traditional hitchhike or ride share?

CB

Ride share is still the dominant way to get into orbit. You have some dedicated launch but it is limited due to cost as well as the availability of right size vehicles to do that. We've also seen deployments from the International Space Station. Satellites are going up on a cargo vehicle to the ISS and then deployed out of the airlock. That's been a great way to get into orbit, especially for university projects that are funded by NASA or other international space agencies.

However, launch has been a bottleneck. It's challenging to get a launch or the right launch. Are you launching when you want, is there a delay, and are you launching where you want to? Often with ride shares, you can't go to your exact orbit, so it's more liking getting on a bus, getting dropped off and then figuring out how to get to where you want to operate. That ties back to the importance of propulsion, because those capabilities help you maneuver that gap.

We have a huge array of startups looking to address that issue, to provide dedicated smallsat launches at a more reasonable price and higher level of availability. So, operators who want more control and flexibility over their launch may feel it's worth it to pay more to launch on schedule and get to their orbit.

Constellations

NASA is coming up with its venture class launch services (VCLS) that could help answer the question about launch capabilities for smallsats. Will that change the situation?

CB

It could. NASA has awarded three VCLS contracts to date, and these players are trying to provide those dedicated smallsat launches. It certainly helps when you have government investment. We saw that on the larger launch side with NASA funding the SpaceX development of the Falcon 9 for cargo deliveries. That can have an impact but we need more private investment. There's also a technical challenge. NASA's work on VCLS helps but we need to see much more advancement.

Constellations

Smallsats like the u-class size CubeSats do not have internal propulsion. There's talk of electric propulsion. Your take on this concept?

CB

We need to see more propulsion capability for smallsats and many are working on it. It's important for collision avoidance and for optimizing the launch. There's an array of electrical and chemical solutions, and I wouldn't pick a winner in that race because the propulsion type is unique to the mission requirement. What sort of mass are you moving, to where, and how quickly do you want to get there? There are trade-offs along the way.

Constellations

Do you think smallsats will ever live up to the hype?

CB

There's been lots of hype around this market, both within the space industry and more broadly in the mainstream media. There were promises from smallsat players about the value that could be created, and we're still waiting.

We've seen consistent delays in deployment. We only have one operational constellation and it's still building out the business. And smallsat operators are adjusting their business plans in response to a constantly changing market. People are working on many different elements to bring that hype to fruition but we've only begun to scratch the surface.

Constellations

Thank you, Carolyn Belle.

Want to hear from more movers and shakers? Listen to the Constellations podcast. Subscribe at:
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The New Satellite World Order

A Newtec Perspective

The industry is undergoing profound change — a paradigm shift is occurring with satellite capabilities and this new era is going to fundamentally affect all as we move forward into the future.

The satellite industry has long held broadcast at its core — now, these market segments are moving toward a more data-centric reality. Users want more data than ever before and they want this access everywhere, whether at home, at work, or on the move — at sea, on land or in the air. This demand for data has been the driving force for the development of new, smallsat 'mega' constellations that are moving away from the 'traditional' *Geosynchronous Orbit* (GEO) into *Low* and *Medium Earth Orbits* (LEO/MEO). This uncharted territory and the industry is about to be tested as never before.

The satellites of the future are going to demand much from the ground equipment that is used to support them and this is a concern that has been at the forefront of **Newtec**'s work for some time. Satellites in LEO, MEO and GEO orbits, with varying payloads, have different demands. This means that flexibility, agility and dynamism are essential to meet these varying requirements.

The LEO Challenge

The new breed of smallsats that will bring about this disruptive transformation in the industry carry a variety of payloads and feature on-board processing.

These smallsats will demand make-before-break beam handover technology to operate, using newly-developed flat panel antennas that will allow for greater mobility. They will also demand highly efficient beam switching as new *High Throughput Satellite* (HTS) systems use multiple spotbeams to allow mobile connectivity.

This demand for high data rates for mobile applications requires a platform that can deal with the industry changes and future connectivity.

Analyst firm **Northern Sky Research** (NSR) forecasts that wholesale operator revenue from non-geostationary constellations is expected to post a compound annual growth rate of more than 40 percent during the next decade. The benefits of non-geostationary satellites include very high-throughput, service reliability, cost-effectiveness, low latency and overall superior broadband performance.

Newtec has been closely watching developments in LEO satellite technology. Critical is that the company's modem portfolio, combined with next-generation, on-board technologies, be ideally suited to bring maximum efficiency and throughput to customers.

Newtec has recently performed successful over-the-air tests on **Telesat**'s inaugural LEO satellite. Launched in January of 2018, the tests on the Ka-band payload are ongoing,and Newtec's technology is being used to demonstrate different service scenarios.

The latest trials witnessed test user traffic successfully passing through the satellite via Newtec modems, revealing that flawless operation of very high-throughput services without packet loss can be achieved via LEO constellations.

The constellation is designed to deliver an unsurpassed combination of capacity, speed, security, resiliency, latency and low cost, delivering affordable fiber quality connectivity everywhere. Once fully deployed, Telesat LEO will accelerate 4G/5G expansion, bridge the digital divide with fiber-like high-speed services into rural and remote communities, and set new levels of performance for commercial and government broadband on land, sea and in the air.

The tests have demonstrated that Newtec's equipment works seamlessly with LEO satellites and that Newtec's technology is already able to deliver next-generation connectivity today.

Image is courtesy of Kymeta.

Panasonic's eXConnect global inflight broadband connectivity.

The Rise of the FPA

While LEO satellites have the power to allow broadband connectivity everywhere, also important is to realize that satellite terminals are designed to transmit and receive signals with satellites that are moving quickly in orbit around the Earth.

Traditional parabolic antennas can be used for on-the-move communications, but they tend to be heavy and bulky and contain many moving parts that can fail. Working with *flat panel antenna* (FPA) manufacturer **Kymeta** and Newtec partners **Liquid Telecom**, **StratoSat** and **Intelsat**, Newtec has recently been able to demonstrate impressive performance over the company's ***Newtec Dialog***® platform on a long road trip across South Africa.

The network tests were run using Newtec's ***MDM3310*** modem on Liquid Telecom's ***Newtec Dialog*** platform over the Intelsat ***Epic^{NG} IS-33e*** Ku-band satellite. The tests achieved the highest available throughput over an Intelsat Epic^{NG} satellite, even for a contended network service. The system, mounted on top of an SUV, made the trip all the way from Johannesburg to Cape Town, operating continuously during the 1,400 km. journey. The system performed exceptionally well.

Connectivity in the Air

Newtec's work within the commercial aviation industry has seen rapid expansion over the last year.

Newtec's MDM3310 modem.

The company's partnership with **Panasonic Avionics**, established in 2016, has resulted in the development of a new, high-bandwidth satellite modem that operates over high-capacity satellites, such as ***Intelsat EPIC***, ***SES-15***, ***Telesat Vantage*** and ***Eutelsat 172B*** that accommodate applications such as *In-Flight Connectivity* (IFC).
In October of 2018, Panasonic Avionics had 350 aircraft flying with the Gen3 Newtec modem to provide IFC and plans to have 1,000 flying with the modem by early 2019.

The Newtec modem offers Panasonic Avionics' aero customers as much as 20 times the bandwidth of their original solution and can facilitate the increasing bandwidth coming on stream as HTS and *Extreme-Throughput Satellite* (XTS) services continue to be layered over the company's existing global network.

With Panasonic Avionics, Newtec has developed the capability to simultaneously receive live TV and IP data on commercial planes from different beams on the same satellite — a wide beam for TV and a spot beam for data. Panasonic Avionics designed their nexgen HTS network with powerful spot beams for data, overlaid with wide beams for TV.
In this scenario, all three receivers on the Newtec aero modem can be leveraged with one receiver for TV and two to handle the switchover between spot beams.

This identical multiple receiver hardware architecture is also appropriate for handling LEOs, when they become available. Newtec is also working with LEO providers to develop the software required for their satellites. Newtec modems are completely software defined, so upgrades can be delivered remotely via a simple upgrade, eliminating the need to swap out hardware.

Mobility Key to the Future of SATCOM

Mobility is set to play a crucial role in the future of satellite communications — user dependence upon data means that we need it wherever we go, for a multitude of different reasons. Combine this with the emergence of mega constellations in LEO, that will deliver unrivaled access to high-speed connectivity on land, sea and in the air, and we have a very exciting prospect before us.

Newtec is prepared to meet the challenges that this new satellite world places before the industry. When deployment begins, our customers can be safe in the knowledge that our platforms will be able to take them where they want to go - both physically and technologically.

www.newtec.eu

www.kymetacorp.com

www.panasonic.aero

The SATCOM IoT Challenge

A SatixFy Focus

By Gideon (Gidi) Talmor, Vice President, Sales and Business Development

For more than 20 years, there have been implementations of remote monitoring via satellite; therefore, satellite IoT cannot be described as a new technology.

SCADA (*Supervisory Control and Data Acquisition*) was what it used to called and, later, M2M (*Machine-to-Machine*) became the descriptive moniker — large scale implementations have alerted China to floods, monitored pipelines in Kazakhstan or gas-valves in Mexico. All are carried out by VSAT networks and L-band providers.

Today's ***SATCOM IoT*** (satIoT) needs are essentially the same but now "on steroids"— larger networks, more remote locations, less available power, lower prices and a new, nearly impossible, twist — mobility — have now all entered the fray.

Large distributed assets are expected to remain connected while on the move. Terrestrial wireless connectivity is the norm; however, vast areas for service deployment can overwhelm many terrestrial distribution business plans and low-cost hardware and usage pricing solutions are needed for satellite IoT. Plus, in addition to the routine messages of temperature, pressure, location, and so on, there are new requirements that are emerging thanks to ubiquitous online connectivity demands.

Several examples come to mind; a camera sending daily pictures of a remote field to monitor growth, pollution or vermin; emergency messages from a truck sensor detailing off-route stops (***GEO-fencing***) and emergency response from a dispatcher to dead-lock the cargo and the truck's brake system; technician needing to log into and re-configure a base station during down-time when no other communication lines are active; software security patch updates to large number of edge devices such as meters, oil field machinery or locomotives; occasional calls from a service personnel at a gas field... and the list of instances goes on and on.

Armed for Ku-Band Solution

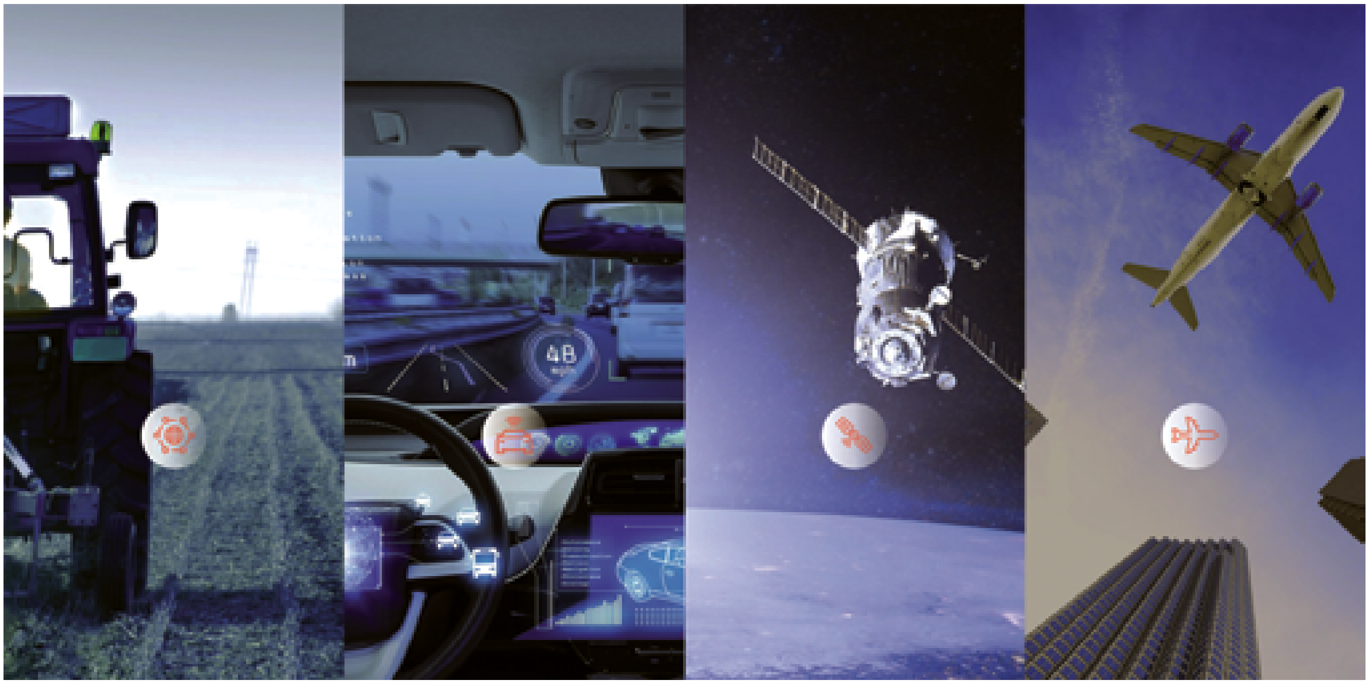
IoT is a growing network of connected devices. Over 50 billion devices are expected to be connected in the coming years in what is described as the next industrial revolution.

Although many of those connections are indoor or in-city, proliferation into most industries is occurring, with the installation of devices such as sensors, meters, actuators, pumps and cameras being connected everywhere — regardless of any terrestrial network's availability.

While most IoT connectivity currently is achieved via terrestrial means, there are many areas not adequately covered by terrestrial networks. As terrestrial IoT solutions become more mature and gain higher penetration into critical infrastructure and utilities, attention is being drawn into redundancy and security issues, which usually leads to SATCOM solutions as the preferred choice. This leads to further expansion of SATCOM in the IoT (satIoT) market.

Still, satellite communication has a limited role in this deployment, with only about 3.5 million M2M devices connected via satellite (according to research and analysis firm, **NSR**) out of about 5 billion devices — that's only a penetration of 0.05 percent. NSR predictions reveal that satM2M deployment in 2020 will reach about five million units, which is a mere 0.01 percent of the expected fifty billion units in service by 2020. In other words, while the IoT industry grew tenfold, the SATCOM penetration into these market segments is expected to decline fivefold.

The main reason for this decline is the lack of a low-priced SATCOM solution that is comparable to the already available terrestrial offerings. This may be attributed to the complete reliance on limited, relatively expensive L-band capacity by satellite service providers. The satellite Industry's main low-priced asset — global FSS capacity — is not participating with any relevance in the IoT game. What is missing is a A Ku-band IoT solution.



The Hardware and Traffic Cost Challenge

The design of IoT devices is relatively simple and inexpensive. These units are deployed in quantities that bring data from large and remote areas without constant observation.

These devices are typically always on and generate occasional, small (but growing) volumes of traffic. Many of these installations last for years and are left to work unattended. Users who place these devices expect connectivity to be thin-routed and highly affordable with the capability to issue occasional, emergency messages or even voice calls. There is little to no budget for professional installation and the locations are sometimes as inaccessible as the dark side of the Moon, meaning maintenance visits are usually out of the question.

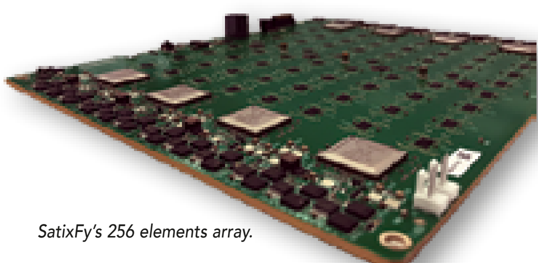
SatIoT terminals must possess identical design considerations: they must be small (about the size of a cell phone); require no professional installation; operate on batteries for a long time; require virtually no maintenance; allow for immediate and guaranteed delivery of emergency messages; enable online access upon demand and possibly even voice calling; do all the above and offer an all inclusive hardware cost of less than $500 with a service fee of no more than $10 per month — even when traffic is high.

No device in the industry, until now, has been able to comply with such specifications. Some L-band models are mobile but don't enable online access. Others enable online access and mobility, but hardware cost is high and, more crucially, once traffic grows beyond few 10's of KBytes, the price of service becomes prohibitive. VSAT implementations by private Ku-band operators can maintain low price for traffic but the hardware has been nowhere near the specification benchmark needed for IoT.

With this in mind, it is easy to understand why satellite M2M is not catching up with IoT market growth and such will continue unless a new, disruptive technology enters the scene.

Enter SatixFy

For several years, SatixFy developed silicon-based ASICs for the satellite market.



SatixFy's 256 elements array.

These ASICs work in tandem to provide the perfect solution for the satIoT market: a complete, modem system on a chip and electronically steered Ku-band antenna based on digital beam forming technology and Ku-band RFIC. Together, these comprise — for the first time — a small, power saving, inexpensive, mobile Ku-band terminal. This technology enables FSS Ku-band operators to take part in the growing IoT market. SatIoT applications can now enjoy airtime costs that are 1/10th the current pricing level and with mobile hardware offered at a lower cost than a mobile phone — and that's the magic... mobile VSAT in a small, inexpensive box.

SatIoT via LEO constellations

New LEO constellations are being planned and some have already launched to deliver satIoT services. When fully populated, these constellations will possess multiple satellites that will relay messages from anywhere on the planet to their recipients using tracking antennas at the IoT terminal.

SatixFy's Diamond IoT Mobility Solution

When the constellation is not fully populated, it can still operate in store and forward mode and that is good enough for many routine message-relay requirements but less relevant for emergency applications, online access or voice calls. The main advantage of LEO IoT is the relatively low cost of the spacecraft and launch — that translates into low operational cost and low $/KB prices.

Other inherent advantages of LEO systems are also present, such as better link budgets (which enable smaller antenna size or higher bitrates) and lower latency. However, these advantages are less critical in the typical IoT use-case, compared with the clear advantage of lower $/KB price promised by such LEO constellations.

Interestingly, when "normal" GEO based, Ku-band capacity is used for satIoT, it can benefit from the low bandwidth prices that are available today, just like LEO systems — sometimes even better. By using tracking antennas like the ***Diamond*** model by SatixFy for example, normal as well as inclined GEO orbit satellites can be used to achieve even lower $/KB prices, making GEO based services cost similar to LEO services.

Mobility, Mobility, Mobility...

To really tip into the growing IoT market, the ability to field mobile IoT terminals is a must — in the terrestrial world, the problem simply does not exist – all terminals are mobile by nature.

Customers expect to have an identical user experience as the terrestrial service when deciding upon a satellite option. Until recently, only a few L-band services were able to offer mobility and even high volume tarric, and even those came with high equipment and service prices.

Mobile terminals by SatixFy tick many required boxes in the industry: tracking for LEO constellations or for GEO satellites; self-pointing on fixed installations that eliminates the need for an installer; re-positioning by the user is trivial, just as though the unit was a cellular-based device; these terminals enable the bulk of the satellite industry to access the huge markets of ground transport, fishing boats, agricultural vehicles and even connected cars. SatixFy believes these new terminals will enable the next revolution of satIoT.

www.satixfy.com

Gidi Talmor has more than 25 years of sales management experience in telecommunications, including satellite technologies, mobile and defence projects worldwide. Prior to joining SatixFy, Gidi was the VP of Marketing for Orbit Communications, VP of International Defence sales at Gilat Satellite Networks, VP of Sales at Clariton Networks, VP of product marketing at Satlynx and General Manager at Charter Kontron.

Feathers...

A Vulcan Wireless TechTalk

By Dr. Stuart Golden, Chief Technical Officer, Vulcan Wireless, Inc.

In this TechTalk feature, a novel approach for remote sensing, communications, and tracking via satellite is presented. Vulcan Wireless (VW) has developed a system that allows low-cost low-power tags to communicate via satellite. This approach is most appealing for low data rate applications in areas where infrastructure is limited — that is, rural environments. It is also highly appealing to coexist with tags that work in more urban environments.

Some of the key applications for this tag include:

- *Pay-per-use bicycle/scooter tracking. These devices can usually be tracked throughout the city by the urban infrastructure (cellular, wifi, specialized base stations, etc…), but at times these devices do not have local connectivity. With the Vulcan Tag the device can phone home even when no cellular is available.*
- *Emergency 911 services for wearables. These small light-weight tags can be embedded in safety hats, jackets, and cellphone cases. By working with your cellphone they allow your cellphone to send text messages, tweets, 911 calls, even when no cell tower is around.*
- *Agriculture sensors are another unique application that is well-suited to this TAG. These sensors can be deployed throughout growing fields where they are monitoring humidity, crops, etc.. and reporting back information via satellite without establishing an expensive infrastructure.*
- *Supply-chain monitoring is another important application. Truck trailers and pallets of materials can be tracked throughout the transportation cycle for big data management.*

Competitive Landscape

Today, there are many low power tag options and many satellite systems new and emerging, but our unique technology has been designed for a special set of applications.

Some of the existing tag options are: LoRa, Sigfox, NB-IoT, NB-fi, Nwave, RPMA, etc… as shown in *Figure 1* below.

A key difference between these existing systems and Vulcan's new approach is that these existing methods require a local infrastructure to operate. That is, either a LAN or WAN infrastructure. These usually manifest itself by WIFI access points or cellular base stations. The TAGs in our system do not require a local infrastructure.

The Disadvantaged TAG

For a low-power tag to communicate with a satellite is a challenging problem and is accomplished by fusing a number of key technologies.

The communication link is a two-way link: the *Uplink* and the *Downlink*. The Uplink is the more challenging of the two. On the downlink, the TAG is the receiver and the satellite is the transmitter. In this case, the satellite is designed to have higher power and the receiver has less interference since the number of overhead emitters is sparse.

However, the uplink creates a different situation. Here, the TAG is the transmitter and the satellite is the receiver. In this case, the TAG is a low solar powered device, so it cannot afford to have a large power amplifier on the TAG, and the satellite's receive antenna is capturing electromagnetic emissions from a significant footprint on the Earth,

DIRECT COMPARISON OF LPWA TECHNOLOGIES PART I

Technology	*LoRa*	*Sigfox*	*NB-IoT*	*EC-GSM-IoT*	*D7AP*
Topologies supported	typically Star, Mesh possible	Star	Star	Star	Star or tree
Max data rate per terminal	50kbps	100bps	60 kbps DL, 50kbps UL	70kbps	166.667kbps
Maturity Level	Early stages - some deployments	in use commercially	early stages	early stages	
Frequency Band	sub GHz ISM bands	sub GHz ISM bands	LTE and GSM bands	GSM bands	sub GHz ISM bands
MAC Layer	ALOHA-based	ALOHA-based	LTE-based	GSM-based	CSMA-CA-based
Range/Coverage	2-5km urban, 10-15km rural	3-10km urban, 20-50km rural	164dB	154 - 164dB	0-5km
Founded	2015	2009	2016	2016	2013
Modulation Technique	Spread-Spectrum	Ultra-Narrow Band (UNB)	LTE-based?	GSM-based	2-(G)FSK
Proprietary aspects	Physical layer	Physical and MAC layers	Full stack	Full stack	Open standard
Nodes per gateway	>1,000,000	>1,000,000	52,000	50,000	
Deployment model	Private and Operator-based	Operator-based	Operator-based	Operator-based	Private
Encryption	AES	Not built in	3GPP (128-256bit)	3GPP (128-256bit)	AES-CCM

DIRECT COMPARISON OF LPWA TECHNOLOGIES PART II

Technology	*NB-Fi (WAVIoT)*	*Nwave*	*Telensa*	*RPMA (Ingenu)*	*Weightless-P*
Topologies supported	Star	Star	Star	Star	Star
Max data rate per terminal	100bps	100bps	—	8kbps	100kbps
Maturity Level	in use commercially	early stages	in use commercially (>9m devices deployed)	in use commercially	early stages
Frequency Band	sub GHz ISM bands	sub GHz ISM bands	sub GHz ISM bands	2.4 GHz band	sub GHz ISM bands
MAC Layer	—	—	—	RPMA-DSSS	—
Range	16.6km urban, 50km rural	10km urban, 30km rural	2-3km urban, 4-10km rural	4km	2km urban
Founded	2011	2010	2005	2008, renamed 2015	2012
Modulation Technique	Narrowband	UNB	UNB	Spread-Spectrum	Narrowband
Proprietary aspects	Full stack	Full stack	Full stack	Full stack	Open standard
Nodes per gateway	1,350,000	1,000,000	5,000	500,000	—
Deployment model	Private and operator-based	Private	Private	Private	Private
Encryption	XTEA	—	—	AES-128bit	—

Figure 1. Comparison of Low-power wireless technologies, excerpt from[1]

which allows the satellite to capture emissions not just from the TAG but also captures significant interference from TAGs and other devices.

Although the satellite antenna aperture is larger than the TAG's aperture, it is limited in size to enable use on a CubeSat. This combination creates a challenge on the Uplink.

On the uplink, a key link budget statistic is the received carrier to noise ratio at the satellite. To improve this link performance, every adjustable aspect in the link budget is optimized. The data rate is lowered to increase the coding gain, add a phased array antenna, optimize the gain and directionality of the TAG antenna, null large interferers with spatial directionality, and remove interferers temporally as well.

By lowering the operational data rate the time duration of an information bit is effectively increased. As the energy per bit of information is equal to the carrier to noise density times, the bit duration the available Energy per bit to Noise Density is increased.

Technology

Sensor Protocol

Each sensor is built with a unique ID/Serial Number that is set in the factory when firmware is loaded onto the Communication's TAG. The TAG also needs configuration parameters to specify how the TAG is utilized. These parameters include: How the Serial ID maps to a Spread Code, the center frequency, the hopping pattern algorithm, the number of retries, and the duration for the TAG to Check-In.

The Check-In time refers to if the TAG should report health periodically even if a detection event has not occurred. This Check-In time can be configured to durations like: once a day, once a week, or never.

Once the configuration parameters have been loaded and the TAG has been deployed, the TAG wakes up if the connected sensor has an event such as "Audio Detection," or the Check-In timer causes the wake-up event.

At wake-up, the TAG sends a packet to the Gateway, and the Gateway responds shortly thereafter. The response is an acknowledgement so that the TAG does not have to resend its message. Certain configuration information can also be changed with the acknowledgement, such as programming a new Check-In time. The TAG then goes back to sleep and waits for the next event.

When a wakeup event occurs, the TAG must first adjust its clock. When the TAG is sleeping, its clock is active and running in a very low-power state consuming less than 1 uW of power. The protocol is illustrated below in *Figure 2* below. The TAG wakes up at a wake-up event, listens for the Downlink to update its time, transmits its information, waits for its acknowledgement, and then goes back to sleep waiting for its next wake-up event.

Scalable CubeSat Constellation

The system that is proposed is genuinely scalable. Operation can start with a single CubeSat or fixed gateway or aircraft or drone, etc...

A single CubeSat can provide worldwide coverage. However the time for which the CubeSat is visible to the TAG is limited. A typical pass might be for 6 minutes every 90 minutes.

Aas more CubeSats are added to the constellation, then the coverage becomes more complete. Also, as the coverage becomes more complete then the capacity of the system also increases since each CubeSat has a fixed maximum capacity. Similarly, by adding additional drone, balloons or fixed base stations one improves both capacity and coverage time over smaller areas.

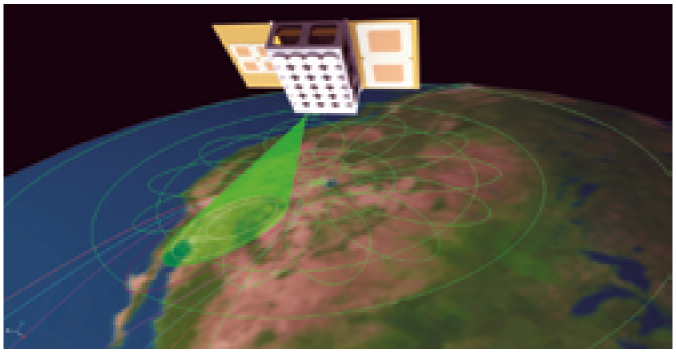


Figure 3. CubeSat with antenna array directing its beam to a particular area of interest.

GPS Elimination

Today GPS receivers are constantly reducing their cost and SWAP (*Size, Weight and Power*). The Vulcan TAG approach supports external GPS receivers as well as the elimination of the GPS receiver. That eliminates the GPS hardware and the antenna.

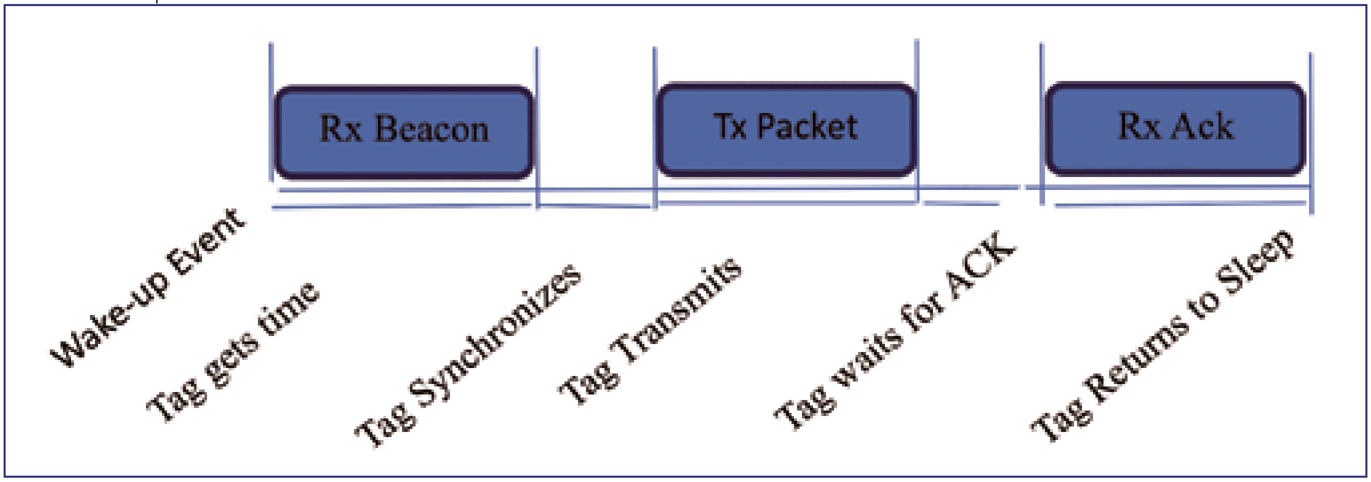


Figure 2: Tag wakes up and uses the beacon to set its clock, then transmits listens for acknowledgement and goes back to sleep.

The lowest cost version of the TAG supports two-way time transfer to the satellite. Accurate time transfer is done by having both the TAG and the satellite work together.

The TAG sends its message at a fixed offset from listening to the satellite and hearing a beacon. The satellite uses this information to trilaterate the TAG. If multiple CubeSats have coverage of the TAG, then they can fuse the information for more reliable location estimates. Similarly, a single CubeSat can get more reliable location information of the TAG by having the report back at multiple time instants.

As shown in *Figure 4*, accurate timing information is determined by using precise timestamps of sending and receiving waveforms using time-of-arrival methods.

used and is the distance between the transmitter and receiver. Note, equation (1) can be very misleading when one is comparing different frequency bands since the transmitted and received Directivity depends upon frequency. The more useful formula is Friis' original transmission equation:

$$P_r = P_t A_t A_r \frac{1}{(d\lambda)^2} \qquad (2)$$

where A_t *is the effective area of the transmitting antenna, and similarly* A_r *is the effective area of the receiving antenna.*

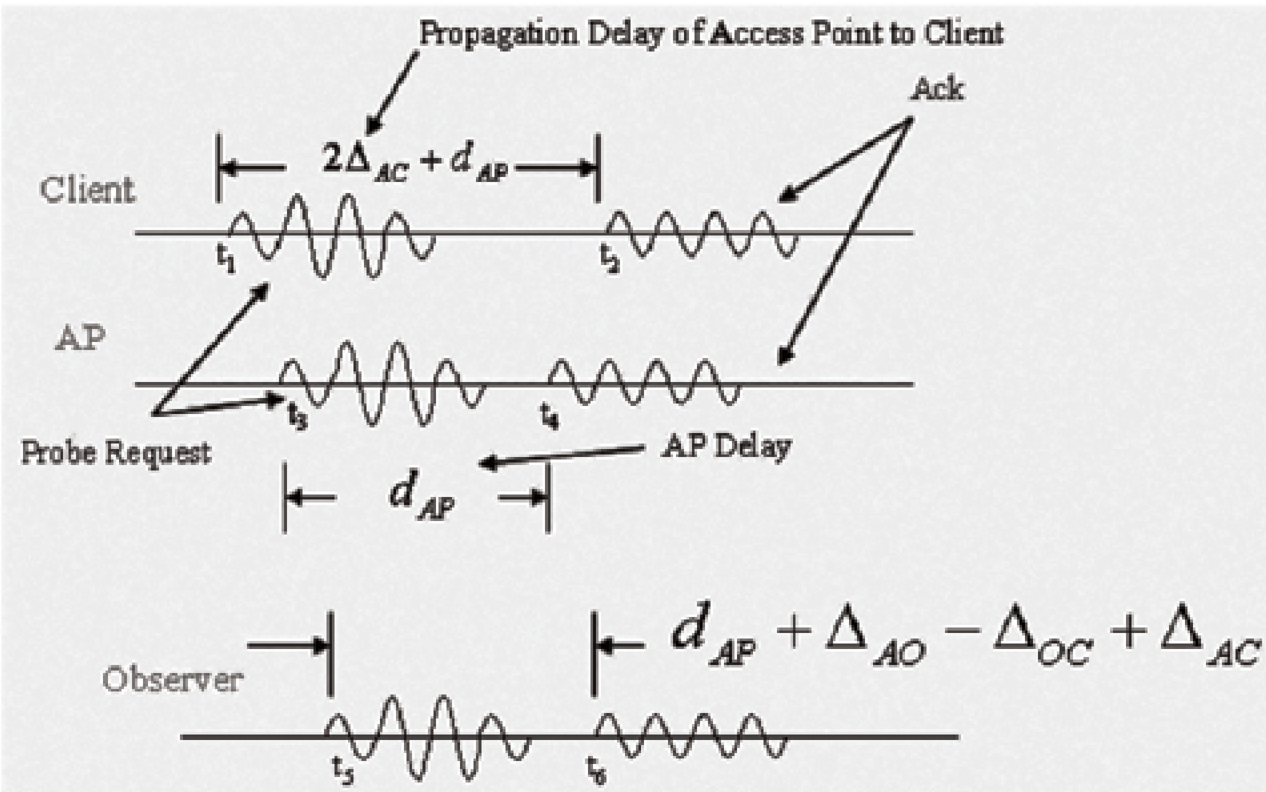


Figure 4: Illustration of Time-of Arrival Ranging, excerpt from[2]

C-Band Phased Array

Where D_t is the directivity of the transmitting antenna, and D_r is the directivity of the receiving antenna, "Lambda" is the wavelength of the electromagnetic wave being used and D is the distance between the transmitter and receiver. Note, equation (1) can be very misleading when one is comparing different frequency bands since the transmitted and received Directivity depends upon frequency. The more useful formula is Friis' original transmission equation:

$$P_r = P_t D_t D_r \left(\frac{\lambda}{4\pi d}\right)^2 \qquad (1)$$

Where D_t *is the directivity of the transmitting antenna, and* λ *is the directivity of the receiving antenna, is the wavelength of the electromagnetic wave being*

In the past, *Equation (1)* was well-used as system designers compared the same antenna design (*e.g.*, monopole) at different frequencies where only the size of the monopole would change. However, *Equation (2)* clearly illustrates that the received power increases as frequency increases for a fixed distance when antenna sizes are fixed. Multiple choices can be used for the antenna selection at a particular frequency such as a dish or antenna array. The antenna array is particularly useful on the CubeSat platform since elements can be placed on the CubeSat structure or deployable solar panels.

The CubeSat antenna consists of an array of antenna patches to electronically steer the downlink to a specific location on Earth. The weights of the antenna elements are adjusted to maximize the transmit gain on the TAG.

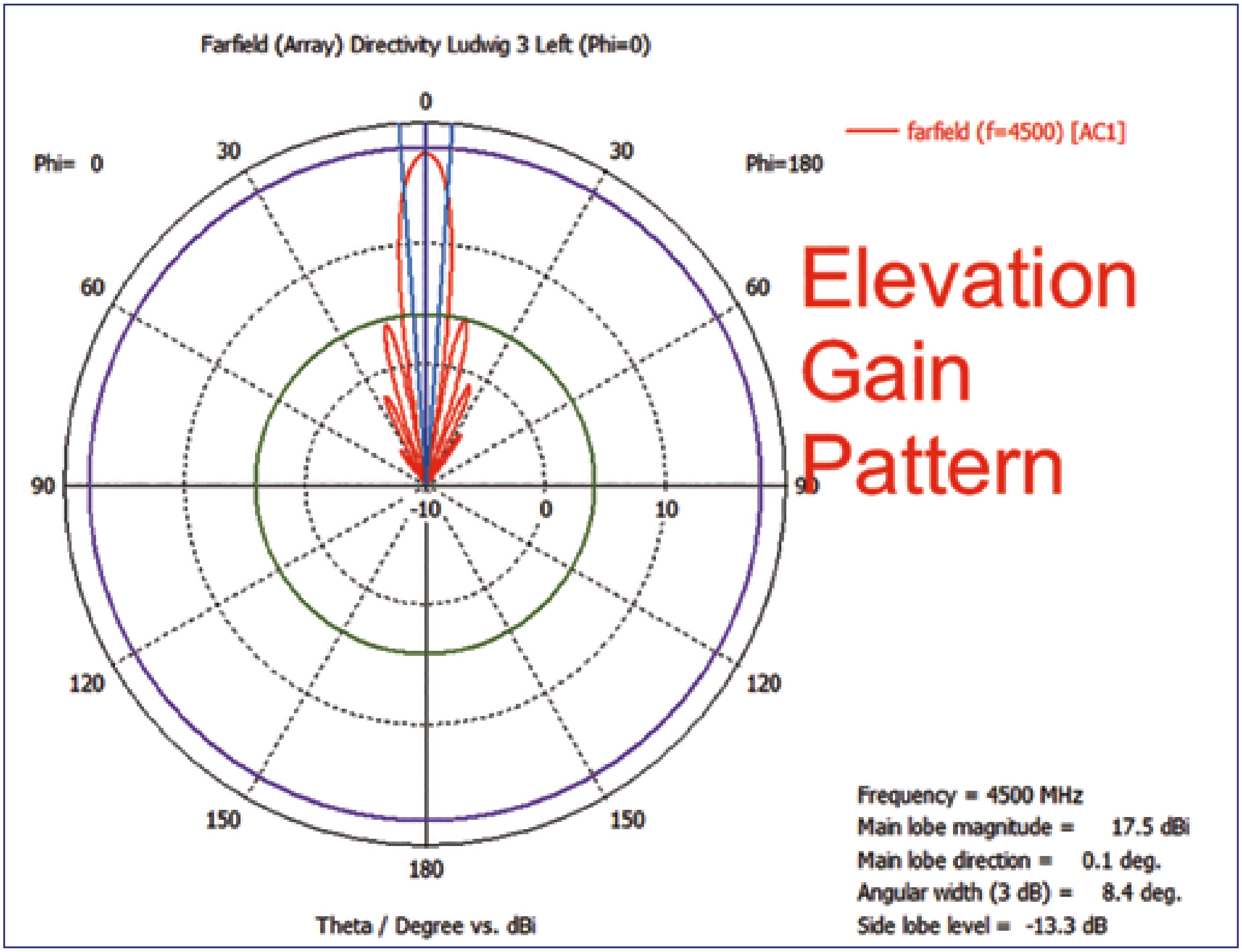


Figure 5: Beam pattern of an individual element from CubeSat's phased array.

Waveform Design

Spread spectrum waveforms are very important to the design of the TAG system. By spreading the signal over a large frequency band interference rejection is significantly improved.

The interference rejection is done in cooperation with interleaving and error-correction coding. If the frequency band is corrupted or jammed and communication is attempted in this band then the communication will typically fail. But if the signal is spread over a larger bandwidth then a narrow band interferer only corrupts a portion of the signal.

Conclusion

Vulcan Wireless is developing a state of the art space-based TAG system for communication and geo-location in remote areas. The development to date includes developing the flight hardware and a demonstrable TAG to satellite communication system that has been tested in Lab and outdoor environments.

www.vulcanwireless.com/

References

[1]*A Comparative Survey of LPWA Networking, J Finnegan, S Brown - arXiv preprint arXiv:1802.04222, 2018 - arxiv.org*

[2]*Golden, Stuart A. and Bateman, Steve S.. "Sensor Measurements for Wi-Fi Location with Emphasis on Time-of-Arrival Ranging." IEEE Transactions on Mobile Computing 6 (2007):.*

Vulcan Wireless has developed a variety of software defined radios for small space vehicles for highly constrained SWaP applications. The company has also built a variety of SDRs that range from tactical UHFSATCOM, S-band transponders to Ka-band transceivers.

Vulcan Wireless provides NSA TSAB protected communication solutions. Additionally, Vulcan Wireless has worked on a wide variety of RF systems ranging from radar, LADAR, Laser communications, satellite, cellular, BlueTooth, 802.11b/g/a, DSL, and cable systems. The firm has extensive experience with embedded antenna designs which require robust electro-mechanical interfaces as well as 3D manufacturing.

Vulcan Wireless has extensive experience in developing digital radio solutions for small satellites and sounding rockets. We currently have many radios on orbit. We have also flown on a Space Loft XL sounding rocket. The following are a few examples of the type of functionality, quality and reliability built into all of Vulcan Wireless products.

The NASA JPS ASTERIA mission used the Vulcan Wireless Radio for its CubeSat mission to study stellar activity, transitioning exoplanets, and other astrophysical phenomena.

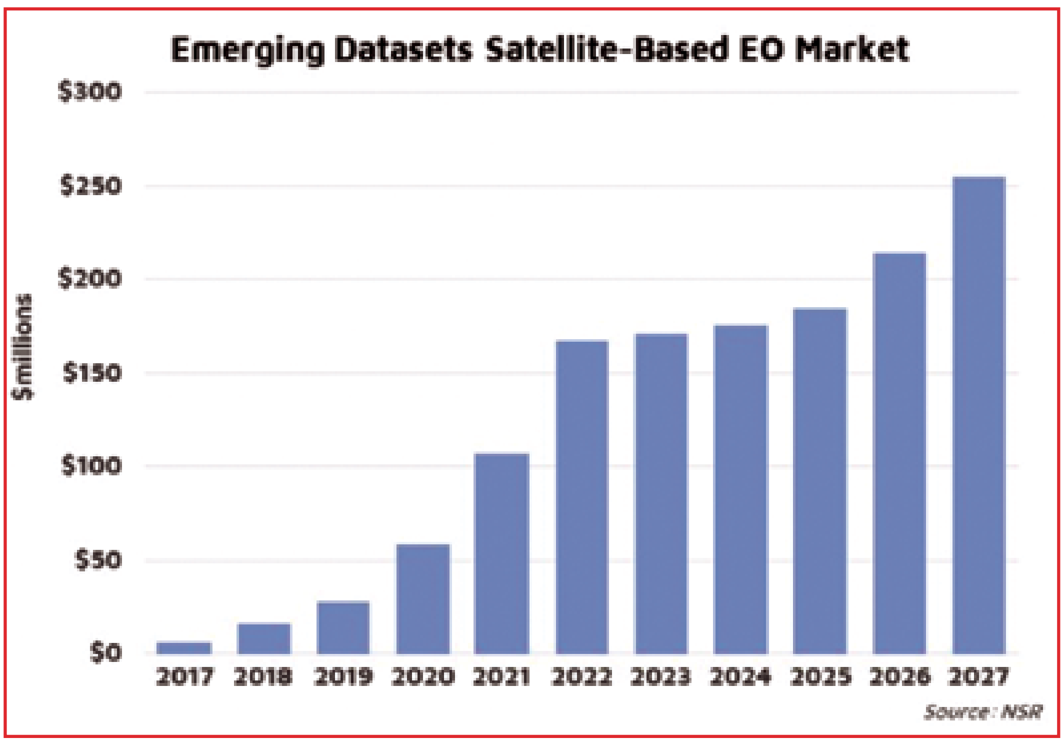
Earth Observation... Not Just Imagery

An NSR Analysis

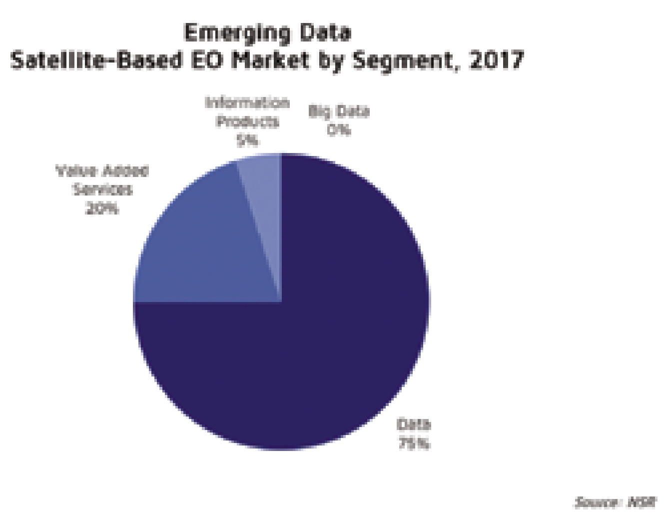
By Dallas Kasaboski, Analyst

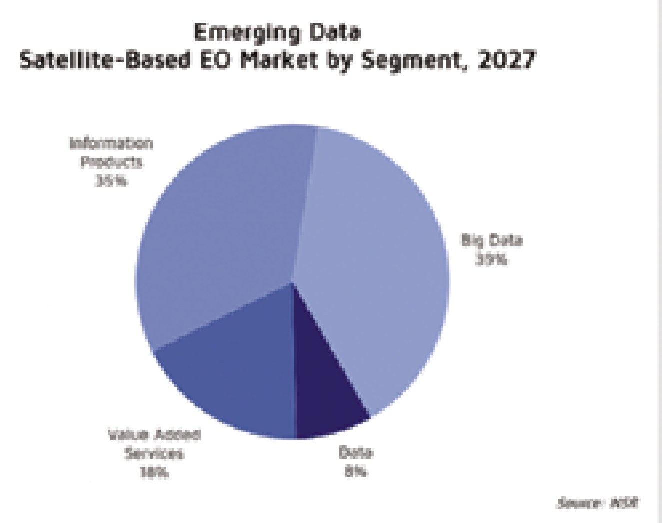
What's next for satellite-based Earth Observation? Driven by technology and competition, the business has grown quickly in recent years. From imagery to insights, from single satellites to constellations, players along the value chain have pushed hard to offer unique services, and the market has diversified and expanded.

In an industry dominated by optical and radar imaging satellites, it is not surprising to see diversification into non-imagery assets, such as the recent announcements from Spire, GeoOptics, and GHGsat. Radio occultation, greenhouse gas monitoring, infrared, the market is expanding, looking for new ways to monitor human activity and the changing world.



NSR's ***Satellite-Based Earth Observation, 10th Edition*** report forecasts the revenue opportunity from non-imagery data to grow to almost $255M by 2027, at a CAGR of 45.7%. Early investment from Public Authorities, Weather, and Energy customers is expected to drive the market, until supply and data pipelines are matured, when Services and Industrial verticals especially will show more interest.





Currently, the revenue opportunity focuses almost entirely on contracts for the provision of atmospheric data. Similar to the development of revisit-driven EO imagery, government agencies are among the first to invest in novel systems, curious as to the quality, reliability, and value of these emerging datasets.

Along with the typical challenges associated with satellite manufacturing and launch, data suppliers will face the obstacle of proving and educating the market as to the value of their data, versus traditional and/or freely-available datasets.

Once supply pipelines are more established, NSR expects product and customer diversification. First, through monitoring services, similar to imagery subscriptions, and eventually to downstream Information Products and Big Data analytics. As such, NSR forecasts the opportunity to shift in the favor of these downstream services, from 5 percent of total non-imagery EO revenues coming from IP and Big Data analytics in 2017 to 74 percent by 2027.

The market is expected to shift quickly, driven not only by overall growth of demand for insights, but also due to the inherently lower value of non-imagery data. Despite the overall market transition away from pixels, a satellite image is still commercially valuable on its own, an argument not easily made for millions of data points pertaining to atmospheric composition.

Similarly, the opportunity for these emerging datasets will be restrained, amounting to only 4% of total EO revenues by 2027. Optical and radar imagery markets are more developed, with established value chains, customers, and solutions, with investment expected to grow.

Furthermore, non-imagery data, while useful, will likely be considered an "add-on," a dataset complementing the intelligence derived from imagery. Niche solutions, such as methane detection from space, may experience strong take-up, but competition, freely-available datasets, and alternative solutions have limited such market opportunities in the past.

Bottom Line

Going forward, imagery will not be the sole supply of satellite-based Earth Observation. Players aiming to offer unique value are developing platforms for infrared, radio occultation, microwave, and greenhouse gas monitoring. While these emerging datasets will expand the market, it is likely that these players will operate and compete primarily in the traditional EO value chain.

As such, players and investors in this space have an opportunity to learn from the mistakes of the past, seeking solid customer relationships, and developing reliable data pipelines and solutions, rather than giving in to the exaggerated interest inherent with new technologies.

www.nsr.com/research/satellite-based-earth-observation-eo-10th-edition/

Mr. Kasaboski joined NSR in 2016. Mr. Kasaboski has a M.Sc. degree in Space Studies from the International Space University, France. During his studies, Mr. Kasaboski worked on satellite mission design, contract negotiation, and was project manager of a team of young professionals investigating unaddressed challenges in one-way human missions to Mars. His team's final work was presented at the International Astronautical Congress in Toronto, 2014.

During the summer of 2014, Mr. Kasaboski interned at NASA's Johnson Space Center. His work involved designing a spacecraft's thermal control system, the mission launch procedure, integration, and operation, as well as evaluating the status of the market of technologies necessary for the mission. Mr. Kasaboski graduated with a Bachelor of Applied Sciences from York University.

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