SATCOM for Net-Centric Warfare – March 2018

MilsatMagazine

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Space Report 2017

MilsatMagazine

MARCH 2018

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DISPATCHES

COMSAT's Thales MissionLink™ Terminal key DoD component

COMSAT has outlined their plans for the Thales MissionLINK terminal as an integral piece of the Department of Defense's (DoD) network modernization architecture for vehicular and dis-mounted units in a Communications-On-The-Move (COTM) environment.

Iridium Certus presents DoD users with a unique capability to reach any number of their devices, platforms or personnel globally and simultaneously through one resilient, secure IP network.

Use cases for global broadcast services, netted user groups, tactical radio augmentation, machine-to-machine/IoT, C2 and C4ISR applications abound, as Iridium Certus is increasingly being recognized as an integral piece of the DoD architecture, as opposed to being a purely commercial augmentation.

Iridium Certus user terminals sign onto the network via a gateway located in the U.S. where all data and voice traffic lands and is seamlessly handed off to terrestrial circuits.

Depending on the user terminal's location and average number of cross-linked satellite hops, the latency in any given connectivity session is as low as 100 milliseconds round trip, which is a substantial improvement when compared to geostationary systems.

This opens Iridium Certus up to a range of latency dependent enterprise applications like video conferencing and secure voice calls.

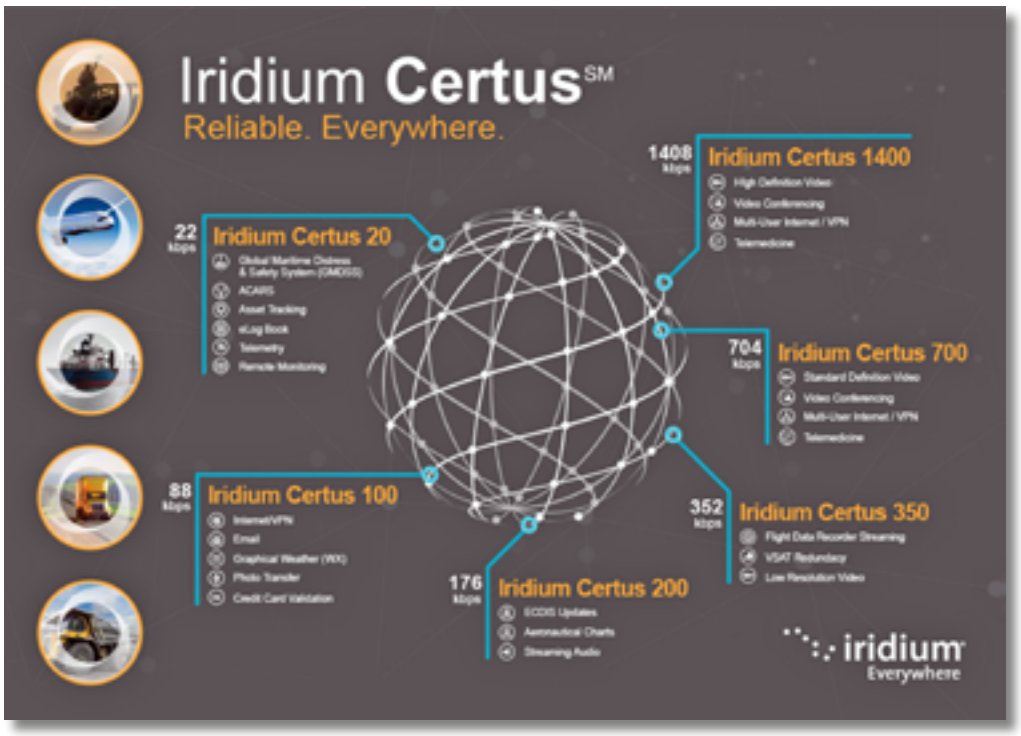
Leveraging Thales' pedigree in "tacsat" and data link comms systems, their Iridium Certus Thales MissionLINK terminal enables the capability to create network level system interfaces to a number of existing DoD standards, building a secure SATCOM node into vehicular and dismounted comms kits.

COMSAT points out that beyond network performance differentiators, Iridium Certus' RF links present a very low probability of intercept due to rapid data path transition between multiple cross-linked satellites that make up the Iridium NEXT LEO constellation.

This rapid path transition also presents strong benefits in terms of network resiliency as connections can be routed around any one satellite anomaly, something that simply isn't feasible in a traditional geostationary or bent pipe network architecture.

comsat.com/

www.iridium.com/network/iridium-certus/



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DISPATCHES

ViaSat-2 satellite comms now available for government, defense and military use

Artistic rendition of the ViaSat-2 satellite.

Viasat Inc. (Nasdaq: VSAT) has announced the availability of ViaSat-2 satellite communications (SATCOM) service for government, defense and military applications.

The service leverages the advanced communications satellite, ViaSat-2, along with innovations in ground networking technologies, that will deliver significant performance advantages over any other commercial or U.S. Department of Defence (DoD) SATCOM system.

In early March 2018, Viasat conducted a ViaSat-2 SATCOM system demonstration — attended by representatives from the U.S. armed forces — and showed a number of cloud-based government applications.

The speeds on the ViaSat-2 satellite system demonstrated the industry's fastest broadband connections, exceeding 100 Mbps during the demonstration day.

The ViaSat-2 SATCOM system has the ability to:

- *Transmit bandwidth-intensive, media-rich cloud applications: Fast data rates and more satellite capacity will enable 4K and HD video streaming to thousands of electronic devices simultaneously for greater operational capabilities at the tactical edge*
- *Conduct more simultaneous operations: Abundant capacity will enable warfighters to capture and send Intelligence, Surveillance, and Reconnaissance (ISR) sensor data; transmit live two-way video conferencing and Voice over Internet Protocol (VoIP) calls; as well as conduct Command and Control (C2) and Situational Awareness (SA) communications as prioritized traffic to many more platforms in a region*
- *Continue operating through an electromagnetic, terrestrial or cyber-attack: Resiliency is provided through the ViaSat-2 system's exceptional anti-interferer performance, Viasat's unique Satellite Access Node (SAN) gateway diversity, seamless satellite switching and assured pattern re-routing to operate through gateway failures, and through Viasat's Active Cyber Defense, which automatically detects, mitigates and attributes Distributed Denial-of-Service (DDoS) attacks against the network's infrastructure. The resilient nature of the Viasat network will enable mission-critical communication packets to be protected and distributed safely, even in highly contested combat environments*
- *Provide assured communications: Viasat's Best Available Network concept provides a global, redundant system for military to access Viasat's global Ku-band networks, its more advanced Ka-band networks, as well as the Wideband Global SATCOM (WGS) system. The Best Available Network allows terminals to roam across multiple networks to maximize resilience and collaboration for ground fixed, transportable, mobile, maritime and airborne platforms*

The ViaSat-2 satellite system validates the performance advantages and capabilities of Viasat's commercial SATCOM system today with a glimpse into the Company's ViaSat-3 SATCOM system capabilities.

Viasat's SATCOM network delivers more bandwidth and better resilience, redundancy and active cyber protection required to maximize operational performance in the contested environments military operations face during combat.

Ken Peterman, President, Government Systems, Viasat, said the company is proudly demonstrating emerging U.S. government concept of operations requiring bandwidth-intensive, cloud-connected military applications with our latest high-throughput commercial satellite, ViaSat-2.

He added that the innovations in the new ViaSat-2 satellite and network show that Viasat can dramatically improve operational capabilities for military missions. This SATCOM system is the first in the company's series of ultra-high-capacity global satellite networks, which will enable superior reach, readiness, and resiliency for global military forces.

www.viasat.com

DISPATCHES

Harris names retired Army General Jeff Smith to VP Position

Harris Corporation has named retired U.S. Army Major General Jeff Smith as the company's Vice President of Business Development, supporting the company's strategic relationships with the U.S. Army, U.S. Special Operations Command and other key industry partners.

Smith brings more than 30 years of leadership experience, including serving as Deputy Commanding General of the XVIII Airborne Corp and command assignments with the 82nd Airborne, 101st Air Assault and 10th Mountain divisions, with deployments to Iraq, Afghanistan and Kosovo.

Most recently, he was Senior Vice President, Strategic Initiatives at Sallyport Global Holdings Inc., where he led their strategy, business development and operations organizations.

Smith holds a bachelor's degree from Columbus State University and master's degrees in strategic studies from the U.S. Army War College and in administration from Central Michigan University.

Harris has been a mission partner with the U.S. Army for nearly 60 years, providing technologies that enable the connected battlefield.

The company has delivered more than one million tactical radios to warfighters around the globe and is on the program of record for all major Army radio modernization initiatives.

Harris provides advanced solutions for multi-domain command and control (C2); intelligence, surveillance and reconnaissance (ISR); strategic and tactical SATCOM communications; electronic warfare (EW); and space innovation that enable the Army to quickly adapt to changing or future needs.

The company is building adaptable systems for the future that leverage open systems architecture and software-defined capabilities to ensure mission success, even in contested environments.

www.harris.com

DISPATCHES

GATR's TRAC antenna is positioned for widespread use

GATR TRAC photo is courtesy of GATR Technologies.

The Department of Defense (DoD) now has access to a portable antenna with tracking capability that can be deployed in places where these capabilities have been traditionally limited.

With support from the U.S. Air Force (USAF) Small Business Innovation Research/Small Business Technology Transfer Program and the Air Force Research Laboratory, Alabama-based GATR Technologies developed a version of its inflatable antenna that can follow moving targets.

Also known as GATR TRAC, the new antenna is relatively lightweight and has a low-stowage volume so it can be easily transported then quickly assembled.

Tracking antennas are used to communicate with satellites in non-geostationary orbits, as well as with other moving objects such as aircraft.

However, legacy systems require a rigid dish with heavy-duty structural support making them difficult to use in many situations.

GATR, which was acquired by Cubic Corp. in 2016, has already begun selling the new product to military and commercial customers.

Early SBIR/STTR support from multiple organizations — including the U.S. Air Force and Missile Defense Agency (MDA) — originally helped GATR to develop 1.2 meter, 2.4 meter, and 4.0 meter inflatable antennas to be anchored to the ground and fixed on communications satellites in geostationary orbit. The company has sold hundreds of these to the DoD.

With more recent support from the Air Force SBIR/STTR Commercialization Readiness Program and AFRL, the concept was refined to create the 2.4 meter GATR TRAC that features mechanical and electrical components in a ruggedized base with support arms that allow the antenna to track satellites moving across the sky.

To develop an inflatable tracking antenna, the company had to overcome the challenge of grasping a large flexible ball-shaped radome and pointing it accurately under varying weather conditions.

The design evolution included improving reliability, creating a simple user interface, and upgrading assembly and disassembly procedures.

GATR TRAC has been demonstrated to reliably track satellites in LEO and produce usable imagery as part of a deployable ground station. The unit also has the ability to track satellites in other types of orbits.

The product packs into four cases that can be checked as airline luggage or shipped by traditional package delivery services, which lowers its cost of use while providing greater overall flexibility to mission planning. Assembly takes approximately 30 minutes.

The company has already logged more than $2.2 million in sales of the new tracking antenna to the military, as well as a commercial customer that supports the DoD. With hundreds of projected smallsats in LEO that will require tracking antennas, GATR TRAC is also well positioned for a potential boom in demand.

GATR's recent successes — from its acquisition by Cubic to sales of its latest portable tracking antenna — are a critical benchmark for participants in the Air Force SBIR/STTR Program.

This type of commercialization helps to bring down costs and get technology to the warfighter while spurring the economy through small business growth.

Peter Ricci, an engineer with AFRL's Information Directorate, said that the GATR TRAC system is a significant step forward over traditional satellite communication systems available today. It affords the user the ability to easily transport and set the system up in remote areas where it once was logistically impossible.

www.gatr.com/

DISPATCHES

Major orders for Spectra Group

Spectra Group (UK) Ltd. has announced the receipt of a series of significant North American orders for SlingShot, Spectra's BLOS COTM (Beyond Line Of Sight Communications On The Move) system for tactical radios.

Already popular with specialist users in the U.S., iSpectra Group has received a total of 12 separate orders with a combined value of over GBP £2 million. The SlingShot orders have been placed by undisclosed U.S. partners and are for use by a variety of end-users.

SlingShot is a unique low SWaP system that enables in-service U/VHF tactical radios to use Inmarsat's commercial satellite network. Including omnidirectional antenna for the man, vehicle, maritime and aviation platforms, the tactical net can broadcast over 1000 kms between forward units and a rear HQ, no matter how or where the deployment. In addition to C2 voice, the system enables data capability supporting mission critical applications such as; artillery fire missions, GPS tracking and biometric analysis. With reduced cost compared to traditional TACSAT, increased channel availability and almost no increase in the training burden, SlingShot is redefining tactical communications. Spectra has strategic relationships with both Inmarsat, whose L-TAC™ service uses SlingShot and Airbus which brands SlingShot as TREx services.

Simon Davies, CEO at Spectra Group (UK) Ltd said that these recent orders further consolidate the company's position in the U.S. market and prove, again, that SlingShot is fast becoming the system of choice for tactical radio users needing to increase range, flexibility and interoperability.

He added that users are really beginning to understand the benefits that SlingShot brings with its excellent utility for coalition interoperability, customs and border patrol, anti-narcotics, maritime patrol, homeland security, National Guard, intelligence communities, police, and emergency responders. Significant amounts of interest regarding Spectra Group products and services is being received from around the globe — the company's attendance at Satellite 2018 is another great opportunity to meet people and explain the advantages of our systems.

spectra-group.co.uk/

DISPATCHES

General Dynamics Mission Systems' Frontier has full interoperability with SKYWAN 5G

General Dynamics Mission Systems Fortress LTE System has Full Interoperability with ND SATCOM's SKYWAN 5G Satellite System

General Dynamics Mission Systems and ND SATCOM recently conducted successful interoperability tests of the Fortress LTE system and the SKYWAN 5G.

The tests demonstrated full interoperability between Fortress decentralized network architecture for autonomous LTE deployables and SKYWAN satellite mesh capabilities for a resilient and bandwidth efficient distributed network of sites with full end-to-end network communications and mobility.

The combined platform provides an ideal solution for transportable and fixed LTE networks that are increasingly becoming a technology of choice for military, tactical, public safety and private mobile users.

The Fortress LTE solution offers autonomous, decentralized LTE sites providing temporary or permanent coverage. ND SATCOM's satellite mesh network solution combined with SKYWAN 5G supplements the solution, enabling direct, single-hop communication between sites.

Fortress LTE products use IP as a convergence layer. The edge centric capabilities of the Fortress Evolved Packet Core, combined with SKYWAN satellite mesh topologies, significantly improve the user experience with reduced network signaling and single hops between rapidly deployable LTE cells.

As a result the OPEX is cut in half which reduces transmission delay and jitter. With QoS mechanisms and real-time services of SKYWAN 5G's MF-TDMA, waveform jitter was validated at less than 10 ms, with an MOS value of four even on overloaded links.

Fortress LTE provides a multi-band capability for global operations making it an ideal fit with the topology flexibility of the SKYWAN solution, including mesh.

The low size, weight and power, ease-of-transport, and simplified management of Fortress LTE enables quick deployment of multiple base stations regardless of existing infrastructure.

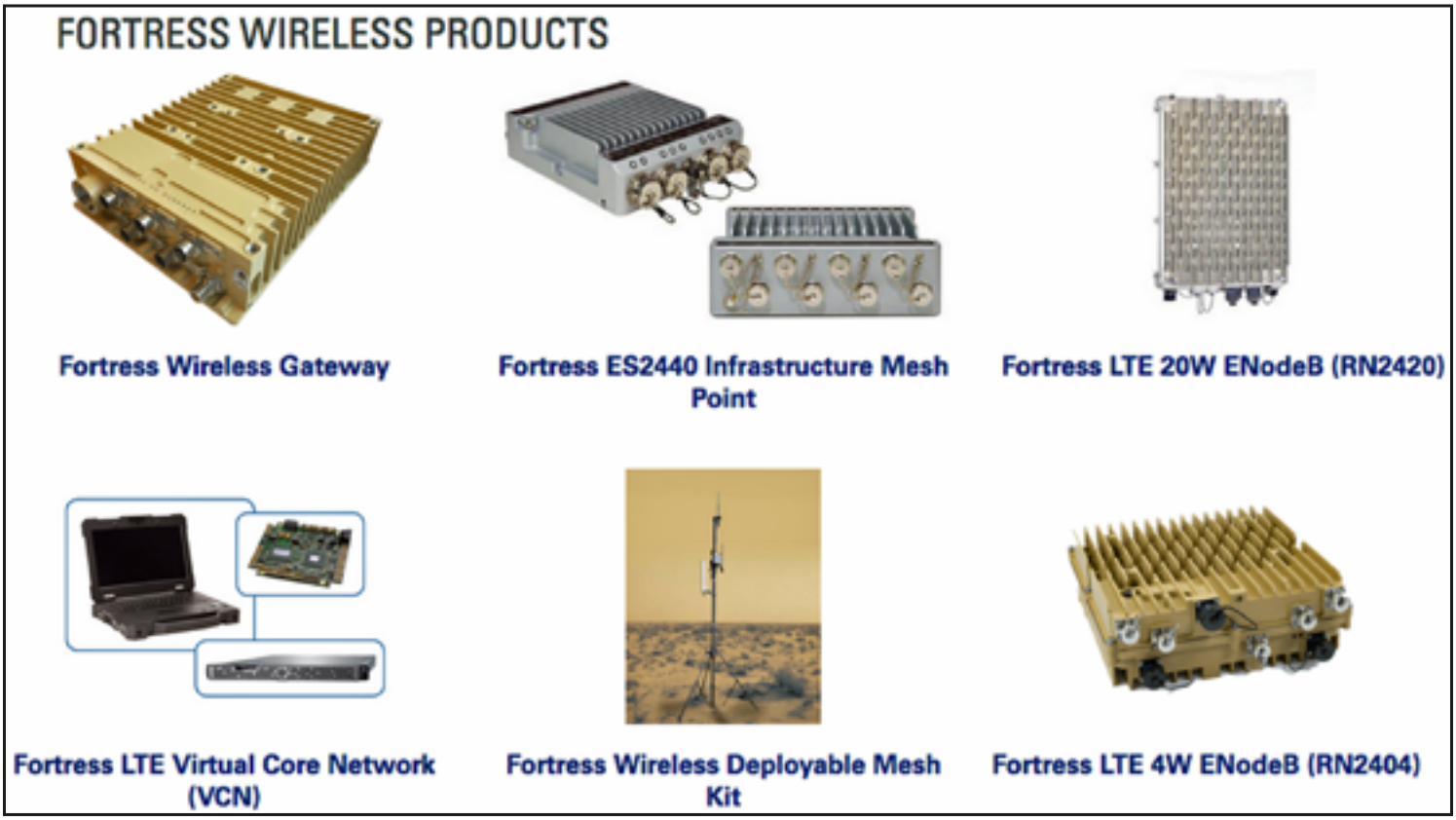
This configuration enables users to roam the network and perform seamless handovers, both inter-cell and inter-EPC with minimal reliance on backhaul links.

Jacek Jarmul, Cellular Backhaul Sales and Business Development Director at ND SATCOM, reported that, over the past month, the company has been actively pursuing the cellular backhaul segment. There is a momentum for the firm's Cellular Backhaul suite (including mesh) in 4G networks which, in comparison to 2G and 3G, can be decentralized and autonomous.

Jacek added that this especially applies to portable and deployable systems for disaster recovery, public safety and similar. Following the requests of the company's customers for comprehensive LTE solutions, including satellite backhaul, ND SATCOM selected General Dynamics Fortress LTE Solutions to expand the company's product portfolio and meet customers' requirements.

gdmissionsystems.com/

www.ndsatcom.com/



DISPATCHES

GetSat receives multi-million dollar bounty from USG for SATCOM terminals

GetSAT, an innovator in lightweight satellite communication terminals for ground, airborne, and maritime applications, has announced that the U.S. Government selected their MicroSAT and MilliSAT L/M (land and maritime) versions for providing maritime and ground-based secure Communications-On-The-Move (COTM) applications.

GetSat's micronized communications terminals are based on the company's patented fully-interlaced InterFLAT panel technology for transmitting and receiving signals on the same panel. Meeting the demanding requirements of full time usage in harsh environments, these rugged Satellite-On-The-Move (SOTM) terminals offer significant savings in size, weight, and power usage.

Constructed in a super-light compact installation, GetSAT's L/M platforms are micronized, fully integrated, on the move rugged terminals. Based on built-in InterFLAT panel technology, all L/M terminals are easy to deploy and integrate, and can be outfitted with various antenna sizes in accordance with bandwidth requirements of ground, air and marine applications. Its unique all-in-one design including BUC and modem is optimized for harsh environments specs and its ultra-low power consuming platform is compatible with Ka- and Ku-Band applications.

MicroSat L/M has options for both the Ka- and Ku-bands, providing autonomous operation for transmitting and receiving bandwidth data rates at more than 10 Mbps. This mid-sized terminal offers unprecedented bandwidth that can be hand carried in any environment.

MilliSat L/M Ka is a medium lightweight portable on-the-move Ka-band satellite terminal solution. MilliSat enables fully autonomous transmission and reception of high bandwidth data rates of more than 20 Mbps.

GetSAT CEO, Kfir Benjamin reported that the company's selection by the U.S. Government is not a surprise. Rather, it is a testament to the company's platforms meeting a myriad of mission critical operations parameters. Soon, GetSat's InterFLAT panel technology, as well as our platforms, will become common names throughout the industry as GetSat continues to provide leading edge communications on the move solutions, platforms and technologies.

www.getsat.com/

DISPATCHES

Resilient space defense technologies under study by SSL for U.S.A.F.

SSL, a Maxar Technologies company (formerly MacDonald, Dettwiler and Associates Ltd.) is leveraging the firm's heritage in developing advanced space architectures and systems to assist the U.S. Air Force Space and Missile Systems Center (USAF—SMC) with exploring new enterprise-level solutions to enable resilient space defense capabilities.

The study is expected to accelerate crucial technologies for future missions as identified within the U.S. Air Force Space Enterprise Vision (SEV), and further distinguish SSL as a trusted partner to U.S. government agencies.

The SEV recognizes the increasing threat to space systems and provides an overarching vision for how the USAF should respond. In addition to enabling a more affordable and resilient national security space enterprise, the SEV shapes future space architectures intended to protect and defend our nation's space capabilities against emerging threats.

SSL brings extensive expertise in the development of foundational and resilient space solutions to the study, including technologies for space infrastructure, affordable access to space, commercial data processing, and small satellites with the capability to support a broad range of future USAF missions.

SSL is working across the U.S. Department of Defense, civil, and commercial space communities on several leading-edge programs and studies that are expected to help U.S. government agencies define next-generation space technologies. These include the Payload Orbital Delivery System (PODS), a rideshare technology scheduled for its inaugural launch on an SSL-built satellite in 2018, Dragonfly robotics for on-orbit assembly, and sophisticated technologies for on-orbit GEO and LEO satellite servicing.

SSL is also assisting the USAF develop a secure interface for hosting government payloads on commercial satellites, designing power and propulsion systems for NASA's deep space gateway, and developing concepts for advanced SATCOM.

Richard White, the President SSL Government Systems, stated that national and global security depends on the operational continuity and resilience of the nation's space assets.

He added that SSL is honored to contribute concepts based on the firm's depth of experience to help accelerate the innovation needed for the U.S. Air Force to achieve its Space Enterprise Vision. SSL delivers proven commercial practices to design and build end-to-end space systems that can improve resilience, cost, and speed for government customers and help protect the quality of life for us all.

www.sslmda.com

Artistic rendition of the on orbit robotic satellite assembly spacecraft, Dragonfly. Image is courtesy of SSL.

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HELPING OUR MILITARY WIN THE SPACE WAR

How commercial use laws come into play...

By Eric Moltzau, Senior Vice President, Business Development and Strategy, Eutelsat America Corp.

Over the last three decades, the United States military has become completely reliant on space-based systems for communication, GPS navigation and precise targeting.

With just one space-based attack, China or Russia could significantly impair the United States military's ability to effectively conduct operations. In an era when adversarial nations are actively building space weapons and targeting U.S. satellites, the Pentagon no longer has the luxury of spending 10 to 15 years procuring a satellite when commercial industry can deliver this capability in two to three years.

As U.S. Air Force Space Commander General John Raymond stated, "*exquisite satellites that last for decades, that cost extremely high amounts of dollars, that take years to build with little regard for today's strategic environment are not that helpful.*"

Fortunately, the federal government is in the midst of a commercial revolution. With senior military leaders and Congress advocating and codifying commercial preference, the pendulum has swung from design-build to commercial first. Though this transition is not new, it is gaining momentum.

In 2010, President Obama made the official National Space Policy that agencies should "*purchase and use commercial space capabilities to the maximum practicable extent when such capabilities and services are available in the marketplace to meet United States Government requirements.*"

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This official policy is consistent with 10 USC § 2377, which requires the head of an agency to modify solicitation requirements and procurement policies to accommodate commercial items "*to the maximum extent practicable.*"

Despite official policy and statute the Department of Defense (DoD) has struggled to break away from its traditional procurement practices as illustrated by a recent court case involving the Army and a commercial vendor.

After the vendor sued the Army in 2016 on the grounds that the bid-solicitation process ruled out any commercially available options, the Court of Federal Claims determined that the Army failed to comply with 10 USC § 2377, which requires market research to determine commercial availability.

Following the court's decision, the Office of the Secretary of Defense for Acquisition, Technology, and Logistics released a "***Guidebook for Acquiring Commercial Items***," noting that "*the quality of the market research affects the quality of the competition.*" Though this new guidance has been instructive and the court ruling sets an important precedent, this is by no means the final word on this issue.

For the commercial space sector, the decision will have a significant impact on the agency-wide acquisition policy related to commercial SATCOM.

As the Department of Defense (DoD) conducts their ***Wideband Analysis of Alternatives*** (AOA) to decide what military SATCOM will look like once the Wideband SATCOM program concludes in 2021, the market research now being conducted will have long-term consequences for commercial SATCOM as well as for commercial use law.

As 10 USC § 2377 states, "*in conducting market research, the head of an agency should not require potential sources to submit more than the minimum information that is necessary to make the determinations.*"

The burden, therefore, is on the U.S. Air Force to fully evaluate commercial SATCOM providers and leverage their capabilities to the maximum extent practicable.

With the results of the Wideband AOA expected to be released this summer and numerous commercial players capable of meeting department needs, commercial preference laws should weigh heavily on the minds of senior officials.

Acknowledging the department's need to fully evaluate commercial capabilities, top U.S. commanders including U.S. Strategic Commander General John Hyten and General Raymond have embraced proposals to partner with commercial SATCOM providers. From hosted payloads to commercial programs, commercially leveraged solutions have already proven to be successful at NASA, the FAA and the Air Force.

With greater integration of commercial and military satellite architectures, the reliance on commercial satellites could be greater and military communications could be far more secure. As General Hyten and General Raymond have both said, distributing military communications through commercial SATCOM satellites increases the military's resilience and ensures no single point of failure.

In practice, however, the tendency to issue solicitations that maintain the status quo means that requirements are not always based on commercial capabilities. For instance, the Air Force released a Sources Sought Notification and Request for Information in November for a follow-on to

the Space Based Infrared System (SBIRS), which provides early-warning capability to the nation's missile defense system.

The solicitation states that the Air Force plans to award a sole source contract to the current prime contractor, Lockheed Martin Space Systems Company. The U.S. Air Force plans to field an SBIRS replacement by Fiscal Year 2029.

As General Hyten asked at the Reagan Defense Forum in December, "*why does our process say it takes 12 years and it will be risky*" when the commercial sector can do this within three years?

This recent SBIRS follow-on solicitation illustrates the DoD's tendency to buy large, geosynchronous satellites rather than take advantage of the abundant number of commercial hosting opportunities.
When there are less expensive satellites available and opportunities to launch using commercial payload services through the USAF SMC Hosted Payload Solutions (HoPS) office, old methods of procuring and building a satellite can prove to be fiscally inefficient and also unnecessary.

At a time when continuing resolutions and budget constraints have become the new normal, it is in the DoD's best interest to ensure that it complies with §2377 throughout the market research process and leverage a competitive commercial satellite marketplace.

With the first WGS follow-on satellite needed as early as 2021, the U.S. Air Force should use the Wideband AOA as an opportunity to fully integrate commercial SATCOM and MILSATCOM to prevent capability gaps.

With space becoming a more contested and congested environment, U.S. access to space is no longer assured. When commercial companies can meet military space program needs, the DoD must urgently overcome outdated acquisition processes in order to get critical communication capabilities to the warfighter as quickly and affordably as possible.

www.eutelsatamerica.com/

DANGER! DANGER!

ASAT weaponry and orbital debris pose extreme spatial challenges

Whether the B-9 Class M-3 General Utility Non-Theorizing Environmental Control Robot was known as "Robot," or "B-9" or the "Robinson Robot," the automaton was a valued member of this space faring family who were widely celebrated during their "Lost in Space" TV series. The program that was produced by famed director and producer Irwin Allen ran from 1965 to 1968.

Why was "Robot" so appreciated (in most cases) by the Robinson family? Basically, for the unit's ability to assist them with their daily work as well as in the detection of threatening conditions. "Danger, danger!" Robot would call out. Its arms and hands would wave up and down in a fashion that could only be surmised as frantic, accompanied by an impressive light display within the robot's transparent "head."

"Danger, danger" is definitely the case when considering the disastrous, debilitating effects of orbital debris as well as the threat of ASATs (AntiSATellite) upon on orbit military, agency and government (MAG) satellites. Far beyond simply disconcerting, this threat is downright intimidating for those whose thought processes range beyond deciding who to vote for as the next song or dance contest "wannabe star."

John Rood, the U.S. Undersecretary of Defense for Policy.

Regarding ASATs and space-based conflicts, during a recent U.S. House Armed Services subcommittee hearing to examine the role of strategic forces, *John Rood*, the undersecretary of defense for policy, stated that preparations are being initiated by the Pentagon should an attack be conducted by adversary states upon U.S. space systems and satellites.

Rood stated, "*And [DoD] space capabilities are critical for effective deterrence, defense and force projection capabilities. Due to the critical importance of these assets, the national security strategy states, 'any harmful interference with, or an attack upon critical components of our space architecture that directly affects this vital U.S. interest will be met with a deliberate response at a time, place, manner and domain of our choosing.*"

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If readers do not believe that ASATs, or orbital debris are credible threats to the security of the nation, then follow the money. Rarely do nations invest in offensive and defensive technologies if a threat is merely smoke and mirrors. Last year, the U.S. committed $11.4 billion in, what Mr. Rood called, "*more resilient defendable space architecture,*" *technology and capital funding.* This year, that amount increased to $12.5 billion.

U.S.A.F. General John Hyten, Commander, U.S. Strategic Command.

The commander of U.S. Strategic Command, *U.S. Air Force General John Hyten* and the Pentagon requested $24 billion to counter any and all adversarial forces that target satellites and other space architectures. The budget submission also included a financing request for the replacement of U.S. space-based assets, should they become disabled or destroyed as the result of an attack upon them.

How could a defense currently be mounted against such assailants? General Hyten's Strategic Command wants to enhance an already-in-place anti-missile missile defensive strategy. Currently in Alaska there are 44 anti-missile interceptors on duty, with an additional 20 such weapons forthcoming. Two additional bases are under consideration, including one on the East coast.

Could such weaponry be used to counter attacks in space? As of this writing, probably not, as the main directive for these defensive weapons would be to counter missile attacks on the U.S. and Allies land-based strategic assets. However, studies and planning are currently believed to be underway to enhance U.S. land-based capabilities to enable them to defend against aggressor space attacks upon valued orbital satellites and other assets.

The best defense is a solid offense — U.S. military commands and R&D agencies are believed to be engaging in the study and implementation of technologies that could be mounted in space or on Earth that would attack aggressor forces and their command structures via direct energy weapons (lasers), cyber attacks, advanced jamming capabilities and other hush-hush technologies.

Russia and China, as well as a variety of additional aggressor states, are already engaged in ASAT development — according to estimates by the U.S. Joint Staff Intelligence Directorate, known as J-2, such weaponry should be operable and in place in a couple of years, all with the aim of incapacitating or destroying LEO satellites.

According to a DoD report, the People's Liberation Army (PLA) is acquiring a range of technologies to improve China's space and counter-space capabilities. China demonstrated a direct-ascent kinetic kill anti-satellite capability to LEO when it destroyed the defunct Chinese FY-1C weather satellite during a test in January of 2007.

A People's Liberation Army (PLA) analysis of U.S. and coalition military operations reinforced the importance of operations in space to enable 'informatized' warfare, claiming that "*space is the commanding point for the information battlefield.*" PLA writings emphasized the necessity of "*destroying, damaging, and interfering with the enemy's reconnaissance... and communications satellites,*" suggesting that such systems, as well as navigation and early warning satellites, could be among the targets of attacks designed to "*blind and deafen the enemy.*"

That same PLA analysis of U.S. and coalition military operations also states that "*destroying or capturing satellites and other sensors… will deprive an opponent of initiative on the battlefield and [make it difficult] for them to bring their precision guided weapons into full play.*"

In the **2017 DoD Annual Report to Congress** — "*Military and Security Developments Involving the People's Republic of China 2017*" (*www.defense.gov/Portals/1/Documents/pubs/2017_China_Military_Power_Report.pdf*) — under the subhead **Space and Counterspace Capabilities**, the report stated that China's space program continues to mature rapidly. "*China also continues to develop a variety of counterspace capabilities designed to degrade and deny the use of space-based assets by adversaries during a crisis or conflict.*"

In addition to the aforementioned January 2007 test, that nation also conducted an ASAT test in May of 2013 that was launched from China's Xichang Satellite Launch Center, located in southwest China. The purported mission was to investigate "*energetic particles and magnetic fields in the ionized startup and near-Earth space.*"

Although not stated publicly, officials in the U.S. highly doubted the Chinese statement and believed this was merely a public relations cover for an ASAT test using a Dong Ning-2 (DN-2) rocket, which reached an altitude of 18,641 miles (30,000 km.). Unnamed U.S. officials at that time indicated the DN-2 would have the capability to effectively ram, and thereby destroy, strategic communication, navigation, or intelligence satellites. A successor vehicle, a

Launch of a Dong Ning-2 Rocket by China.

Dong Neng-3, was also apparently launched on October 30 in 2015. Another Chinese weapon alleged to being tested is a land-based, high power laser generator that can target satellites and will be able to incapacitate electro-optical satellites as well as interfere with Synthetic Aperture Radar (SAR) satellites.

China is unifying their cyber, Electronic Warfare (EW) and space capabilities through the ongoing development of that nation's **Strategic Support Force** (SSF), which was created in 2015 to concentrate on additional offensive capabilities and mobility for the PLA's cyber and space ops. There have also been bilateral military exercises between Russia and China with possible technological exchanges between the two nations.

A technology that is being diligently worked on by the Chinese military-industrial complex is what is known as "***satellite ghost imaging.***" This technology involves the development and build of optical cameras that can peer through most obscuring elements, such as clouds, negating most environmental factors that would normally block imaging capture by satellites. Don't expect China to be the only nation digging into this technology.

Consider — China currently possesses the most satellites in orbit behind the United States. Many of these satellites are covert in nature — those platforms may well carry the capability to attack opponent satellites. China has already deployed two ASAT missile systems which has plans to build even more advanced, ground-launched, ASAT weapons.

Contemplate the wealth of information satellites delivered to U.S. and Allied forces… satellites are a force multiplier in that they manage critical comms between commanders and the battlefield, collect intelligence, surveillance and reconnaissance (ISR) data, handle command and control (C&C) missions, steer offensive weaponry to targets, defend state-owned assets and constantly update damage assessments for weapon re-targeting. As opponent states have stated, without operational satellites, the ability for rivals to defend their resources and to attack others is substantially reduced.

Adding additional fuel to the ASAT fire, the 2017 DoD report indicated that Chinese "*space operations will probably form an integral component of other PLA campaigns and serve a key role in enabling actions that counter third-party intervention. China is seeking to utilize space systems to establish a real-time and accurate surveillance, reconnaissance and warning system, and to enhance C2 in joint operations. These advancements include the Beidou navigation satellite system and space surveillance capabilities that can monitor objects across the globe and in space.*"

Russia is also actively engaged in ASAT development, with a believed focus being on their A-60 and Nudol systems — the former can blind a satellite and the latter is a ground-based, direct ascent missile — the solid propellant launch vehicle for this ASAT has been tested at least three times from the Russian Plesetsk launch facility, with one of these tests successful. Information regarding the number of follow-up launches is unknown as of this writing.

Bring GPS/GNSS/GLONASS/IRNSS/Beidou navigation satellites (navsats) into the discussion and successful ASAT weaponry assaults on those assets would have an immediate affect on the civilian population, as well. Their unavailability would drive much of the populace into a severe state of dismay… dependence upon navsats for civilian and military forces has become more than just a "nice to have" — there is a total dependence upon these satellites for much of what all

The Russian Nudol ASAT system.

accomplish each day to earn a living, communicate with others, defend a nation and to simply enjoy life.

Dan Coats, the Director of National Intelligence.

Dan Coats, the Director of National Intelligence, stated, "*We assess that Russia and China perceive a need to offset any U.S. military advantage derived from military, civil, or commercial space systems and are increasingly considering attacks against satellite systems as part of their future warfare doctrine.*" Simply stated, such commentary should offset any dithering or complacency within the legislative branches of the federal government as to the funding to support the requested offensive and defensive space assets so crucial to the nation's survival.

Coats additionally warned Congress that Russia already possesses a diverse suite of capabilities that would "*affect satellites in all orbital regimes.*" That nation would be able to target and totally disrupt U.S. satellite functionality with an airborne laser.

There are assets that certainly are being considered for use today to offset attacks on U.S. or allied state satellites. The U.S. Air Force's highly secretive solar-powered X-37B autonomous orbiting vehicle, built by Boeing's Phantom Works division, is designed to fly at altitudes ranging from 110 to 500 miles (177 to 805 km.).

The U.S.A.F.'s reusable X-37B

The X-37B could potentially carry technologies for offensive and defensive operations in space. This craft, as of this writing, has already completed four, secretive, orbital missions and may well have conducted more flights than are publicly known. The U.S.A.F.'s 3rd Space Experimentation Squadron, based at Schriever Air Force Base, handles mission control for the X-37B, which is managed by the U.S.A.F.'s Rapid Capabilities Office.

With the X-37B's payloads all classified, the craft's 7 feet long by 4 feet wide (2.1 x 1.2 meters) dimensions could certainly be capable of packing small to medium sized weaponry designed to contradict invader assets — weight would certainly be an issue to be overcome — the X-37B is boosted vertically with the assistance of a launch rocket and lands back on Earth on a runway. And lest all forget, the U.S. has already proven its ability to interdict a satellite — in 2008, a National Reconnaissance Office (NRO) satellite was intercepted by a modified U.S. Navy SM-3 anti-missile and destroyed.

During a recent House Armed Services Committee hearing, *General Hyten* explained that in order to secure space, teammates are needed in order to share intelligence and assets. To that end, In 2017, the Joint Interagency Combined Space Operations Center (JICSpOC) was renamed the National Space Defense Center — initial operational capabilities should be in place by November of 2018, with full operation by the close of 2018.

When the U.S.A.F.'s Space Enterprise Vision (SEV) was announced in April of 2016, a press release from Air Force Space Command (AFSPC) based at Peterson Air Force Base in Colorado included comments from *General Hyten*, who said the organization will become, "*a centralized hub for operational planning and tasking,*" adding, "*SATCOM systems are key to our continued strategic posture in space. We must expand international SATCOM partnerships.*"

The General added, "*In the recent past, the United States enjoyed unchallenged freedom of action in the space domain. Most U.S. military space systems were not designed with threats in mind, and were built for long-term functionality and efficiency, with systems operating for decades in some cases. Without the need to factor in threats, longevity and cost were the critical factors to design and these factors were applied in a mission stovepipe. This is no longer an adequate methodology to equip space forces.*"

The SEV accounts for the increasing threat to space systems and provides a vision for how the U.S. Air Force should build a force responsive to that threat. The vision describes an integrated approach across all space mission areas, coupling the delivery of space mission effects to the warfighter (such as communications, positioning, navigation and timing, missile warning, and weather data) with the ability to protect and defend space capabilities against emerging threats.

Consistent with U.S. National Space Policy, the vision enhances U.S. space forces' ability to deter others from interference and attack, defend our space systems if deterrence fails and contribute to the defense of allied space systems.

"*The future space enterprise will maintain our nation's ability to deliver critical space effects throughout all phases of conflict,*" *Hyten* said. "*Operating as an enterprise as opposed to a set of independent platforms improves resiliency and is critical to the ability to survive and deliver effects in a contested environment.*"

Since the study was commissioned, AFSPC and the National Reconnaissance Office (NRO) have worked together to incorporate principles of the NRO vision as well, with additional work ongoing to fold in the remaining facets of the Defense Departments' space capabilities and the key linkages with the intelligence community.

"*Ultimately, the SEV (Space Enterprise Vision) must incorporate requirements from across the U.S. government's space enterprise,*" *Hyten* said. "*By incorporating interagency space visions, the SEV will fold requirements into a single-enterprise vision that addresses the unique needs of each agency.*"

To guide the development of this future enterprise, the SEV proposes using a new optimizing concept called "*resilience capacity*" to characterize and evaluate space capabilities.

Resilience capacity will measure how well space enterprise forces can respond to the full range of known threats, and how quickly they can adapt to counter future threats, while continuing to deliver space effects to joint and coalition warfighters. It will replace the traditional "*functional availability*" metric used for decades to plan and manage individual constellations, but which does not account for emerging threats.

"*The future space enterprise will be built by changing how we architect, develop, acquire, and operate our space systems,*" *Hyten* added. "*Going forward, we will rigorously focus on a clear definition of warfighter requirements with programs acquired using greater horizontal integration across the space enterprise. We will also move toward shorter program life cycles and decreased time between constellation updates, which improves the availability of new technology on orbit.*"

In the U.S., Space Situational Awareness (SSA) is taking a front seat as a key investment by the DoD, with implementation, for the most part, occurring within the U.S. Air Force. The ability to detect and track smaller objects is a major goal of the space fence program. This should enhance space systems survivability.

Bringing on orbit satellite servicing spacecraft into the picture, if a friendly satellite can be captured, refueled and otherwise repurposed by these spacecraft, certainly their ability to immobilize or otherwise negate an "unfriendly" satellite is within the realm of reason. China is driving development of on orbit servicing and maintenance systems, as is the United States and other nations — is all of this development strictly for peaceful satellite repurposement?

When all of the hyperbole and all of the chatter is reduced to the basics, the realization should dawn that nearly any ballistic missile can be programmed to become an ASAT weapon.

Space Servicing and More...

SSL, a **Maxar Technologies** company (formerly MacDonald, Dettwiler and Associates Ltd.), is leveraging advanced space architectures and systems developments to assist the U.S. Air Force Space and Missile Systems Center (USAF—SMC) with investigations into new enterprise-level solutions to bring solutions to space resiliency concerns.

This study is expected to accelerate crucial technologies for future missions as identified within the SEV, which recognizes the increasing threat to space systems and provides an overarching vision for how the USAF should respond. In addition to enabling a more affordable and resilient national security space enterprise, the SEV shapes future space architectures that are intended to protect and defend our nation's space capabilities against emerging threats.

SSL is working across the **U.S. Department of Defense** (DoD), civil, and commercial space communities on several leading-edge programs and studies that are expected to help U.S. government agencies define next-generation space technologies. These include the **Payload Orbital Delivery System** (PODS), a rideshare technology scheduled for its inaugural launch on an SSL-built satellite in 2018, **Dragonfly** robotics for on orbit assembly, and sophisticated technologies for on orbit GEO and LEO satellite servicing.

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SSL's Dragonfly spacecraft.

In early December of 2016, **NASA** selected SSL to build a spacecraft for the demonstration **Restore-L** mission to repurpose the **U.S. Geological Survey**'s **Landsat 7** EO satellite in 2020. The SSL spacecraft will provide the power, communications and propulsion for the mission.

In February of 2018, the company received an award from the **Defense Advanced Research Projects Agency** (DARPA) to work on the **Robotic Servicing of Geosynchronous Satellites** (RSGS) program to bring their satellite bus and refueling technologies to this project, while DARPA will produce the actual servicing payload as well as launch the satellite.

SSL is also assisting the U.S.A.F. develop a secure interface for hosting government payloads on commercial satellites, designing power and propulsion systems for NASA's deep space gateway, and developing concepts for advanced satellite communications (SATCOM).

Richard White, President, SSL Government Systems.

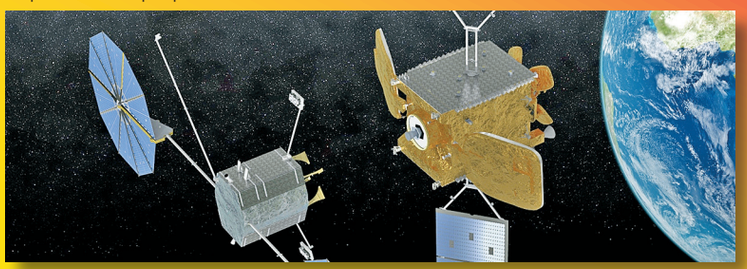
Richard White, the President of **SSL Government Systems**, noted that national and global security depends on the operational continuity and resilience of the nation's space assets and the company is honored to contribute concepts based on the firm's depth of experience to help accelerate the innovation needed for the U.S. Air Force to achieve their Space Enterprise Vision. SSL delivers proven commercial practices to design and build end-to-end space systems that can improve resilience, cost, and speed for government customers and help protect the quality of life for us all.

Maxar, in June of 2017, created a new subsidiary to handle such space servicing work — **Space Infrastructure Services** (SIS) — to develop on-demand robotic service spacecraft that will be available for missions starting in 2021 and beyond. With SIS, the company claims satellite operators will be able to improve on orbit resilience and have unprecedented flexibility for satellite fleet management.

The SIS service arrives at a GEO spacecraft that requires the spacecraft's assistance, completes the assigned tasks within a few days and then redeploys for pre-scheduled and emergency call-up servicing — that seems similar to roadside assistance, except this is in space.

The SIS services are insured and payment is not due until a successful service has been completed. Plus, SIS states the satellite being serviced can continue to operate during most of the robotic servicing procedures. The SIS servicer will be compatible with government and commercial spacecraft — even those not designed to be serviced in space. (***www.spaceinfrastructureservices.com/***)

Another company entering this market segment is **Orbital ATK**'s **SpaceLogistics** subsidiary, which was established to provide cooperative on orbit satellite life extension and maneuvering services to GEO operators via the firm's **Mission Extension Vehicle** (MEV), which is based on Orbital ATK's **GEOStar 3** bus — the unit docks with a customer's existing satellite to provide the propulsion and attitude control to extend that satellite's life.



Orbital ATK's MEV-1 spacecraft.

The company is now producing **MEV-1** for **Intelsat S.A.**, with a launch scheduled for late 2018, with system-level testing starting this spring — Intelsat has also ordered a second MEV (MEV-2). Mission extension services for MEV-1 are scheduled to start in mid-2020, with the MEV-2 launch also expected that year. Both MEVs have a life expectancy of 15 years. The MEVs use a low-risk docking system that attaches to existing features on a customer's satellite and then takes over orbit maintenance and attitude control while performing the servicing work.

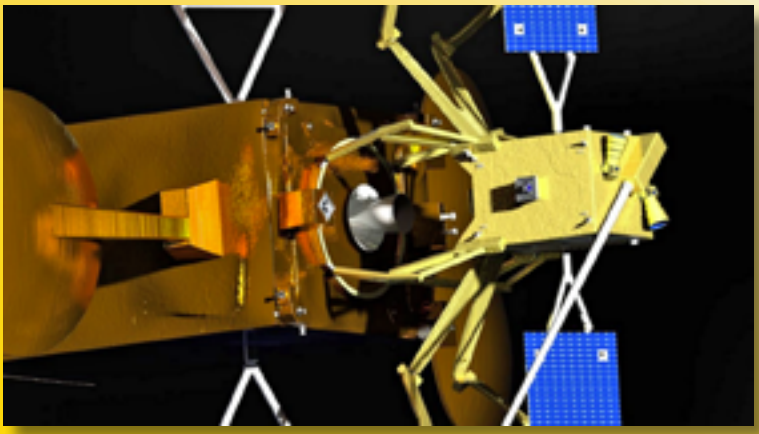
David W. Thompson, Orbital ATK's President / CEO.

During a recent trade show, President and CEO, *David W. Thompson* and President *Tom Wilson* introduced a new robotic servicing sytem that will, according to their information, enable the company to expand their customer base with advanced mission capabilities in this emerging market segment.

Tom Wilson, Vice President and General Manager, Orbital ATK

This new system is comprised of two products — the Mission Extension Pods (MEPs)™ and Mission Robotic Vehicles (MRVs)™. The former is an extral propulsion modules that attaches to, and provides up to five years of, orbital life extension for aging satellites that are running low on fuel, but are otherwise healthy. While the primary application of the MRV is to transport and install MEPs or other paylods on customer satellites, the spacecraft will also offer space robotic capabilities for on orbit repairs and similar functions.

Tom Wilson noted that, while Orbital ATK's space logistics technology roadmap does not directly identify orbital debris as a primary market, the company's roadmap does support some of the challenges of orbital debris mitigation. He added, *"For example, our initial MEV can be used to "tow" disabled, but stable, satellites from the GEO orbits to the GEO graveyard; or return them to service depending on the disability. The company's next-generation system that has just been announced incorporates robotics that will allow for detailed inspections, simple repairs, and installation of augmentation payloads which may enable disabled satellites to return to service.*



Artistic rendition of Effective Space's SPACE DRONE™.

"*Looking into the future, we are developing generic interfaces for future spacecraft that will greatly enhance the ability to repair, maintain and augment capabilities that will enable these spacecraft to return to service rather than become space junk; and the robotics will provide the ability to capture unstable spacecraft for removal from operational orbits.*"

Wilson then said, "*The introduction of MEPs allows us to offer a complementary service alongside the company's MEVs to meet the industry's needs by providing low-risk, low-cost station-keeping for geosynchronous satellites of all types. Orbital ATK always aimed to expand the company's fleet to provide a wide variety of space logistics services, and the MEV, MEP and MRV products give customers the option to select exactly the kind of life extension or in-space repair they may need.*"

A third competitor entering the fledgling satellite servicing sector is **Effective Space** (*www.effective.space/*). The company recently signed a contract with launch provider **ILS** (*beta.ilslaunch.com/*) to push two of their **SPACE DRONE™** spacecraft into orbit in 2020 to handle the station-keeping, relocation, de-orbiting, orbit correction and incline correction and 'bringing into use (BIU) needs of the target satellite.'

The SPACE DRONE weighs 400 kg. and possess a universal, non-intrusive docking system that will rendezvous and then dock to a geostationary host satellite. The SPACE DRONE will then use electric propulsion to support the satellite's station-keeping and attitude-control maneuvers.

The ILS will employ their **Proton Breeze M** launch vehicle to send the two satellites to their destination. The rocket has a lift capability of 6.3 metric tons for satellites heading to GTO launches and 3 metric tons for GSO destinations. Two payload fairings are available — 4.35 meter and 5.2 meters, enabling the launch vehicle to encase single or multiple satellite payloads.

Arie Halsband, Founder and CEO of Effective Space.

Arie Halsband, the Founder and CEO of Effective Space, said, "*Launching our first two SPACE DRONE™ spacecraft into a geostationary orbit is part of our strong commitment to our first customer, meeting mission timeline and ensuring smooth transition into a life-extension service. Due to the attractive economics, extending existing assets in space is something that is gaining significant traction in today's market. With that in mind, the announcement of this launch, utilizing the performance of the Proton Breeze M vehicle, is an important milestone for a rapidly developing market. ILS worked with us to arrive at a reliable, high performing, cost-effective solution for our business. We look forward to our continued work with ILS and Khrunichev to propel this exciting phase of our company forward.*"

Kirk Pysher, President, ILS.

The President of ILS, ***Kirk Pysher***, added, "*The company is focused on serving the satellite industry with flexible, and affordable launch solutions and our agreement with Effective Space is a perfect example of that. The performance of the Proton Breeze M vehicle to deliver the SPACE DRONE™ spacecraft directly to geostationary orbit combined with our decades-long history of launching dual or multiple spacecraft at one time, makes it a natural fit for Proton to deploy their spacecraft. This combination of performance and experience will enable Effective Space to realize their mission objective in the most expedient and effective way possible.*"

Debris Dilemma

In addition to the ever-increasing threat posed by ASATs, orbital debris is of major concern to military, government, agency and civilian entities. Orbital debris is defined by NASA as "*any man-made object in orbit about Earth that no longer serves a useful purpose, including spacecraft fragments and retired satellites.*" Toss in meteoroid particles, which can range in size from as large as 10 meters to clots of dust, and space is a dangerous arena for satellites and other spacecraft.

Chris Blackerby, the COO of ASTROSCALE.

Chris Blackerby, the COO for **ASTROSCALE PTE. Ltd.**, offered the following regarding the importance of orbital debris awareness and removal.

He said, "***One of the most concerning environmental issues for humanity can be found far above the surface of the Earth. The presence of orbital debris is a persistent threat not only to the handful of astronauts who live on the International Space Station, but to the billions of us on Earth who are increasingly reliant on satellites for all aspects of our daily lives.***

"*There are currently more than 100 million objects in orbit that are under 1 cm. in diameter, 22,000 of which are over 10 cm. More than 99 percent of these objects are uncontrollable debris that could cause the destruction of the ISS and thousands of active satellites of all types — security, civil and commercial. Though the chance of a mission-ending collision from a piece of debris on any given active satellite is still unlikely, if an impact did occur it could destroy an on orbit asset instantly and the effects on military activities as well as our daily life would be devastating.*

"*As launch and satellite development costs continue to decrease we find ourselves on the cusp of a democratization of space that will fundamentally alter the next space age, creating multiple opportunities for enhanced military capability and societal benefit while also significantly increasing risks of collision. The congested and contested orbital environment is only going to get more crowded in the years and decades to come and an effective and economical solution for tracking and removing debris is a necessity.*"

ASTROSCALE is a Singapore-based satellite services company that was founded in 2013 with the objective of developing innovative solutions against the growing number of space debris. The company's mission is to actively contribute to the sustainable use of the space environment by developing scalable and innovative on-orbit technologies, in order to safely remove the most threatening debris on orbit.

Artistic rendition of China's Tiangong-1 space station, now in free fall.

In addition to spacecraft debris removal technologies, Astroscale is invested in providing debris monitoring and tracking capabilities. The company has conducted accurate research to collect essential data on small-sized debris that cannot be tracked using the existing ground-based technologies. With headquarters located in downtown Singapore, and a manufacturing facility in Tokyo, the company is actively preparing for its first two missions, **IDEA OSG 1** and **ELSA-d**. (*www.astroscale.com*).

The effect of orbital debris on Earth could not be more clearly witnessed than with the upcoming free-fall of the Chinese 8-1/2 ton **Tiangong-1** space station. Launched in 2011, this was China's first prototype space station and includes hydrazine on board, which has a Group B classification from the **Environmental Protection Agency** (EPA — *www.epa.gov*) as a probable human carcinogen.

Between 10 and 40 percent of the space station is expected to survive re-entry burn through the Earth's atmosphere, with the **German Space Debris Office** calculating impact between **March 24 to April 19** (as of this writing).

The **European Space Agency**'s (ESA) **Space Debris Office** has reported that the fragments of the space station should arrive in locations between 43 degrees North and 43 degrees South, which places the southern sections of northern states in the U.S. as well as several European countries, the Middle East, New Zealand and Tasmania in Australasia as well as southern Africa and South America, as zones where impact(s) could occur (*www.esa.int*).

Thanks to a forecast by the **Aerospace Corporation** (*www.aerospace.org*), falling fear factors should be reduced as that company offers the information that the odds of any individual being struck by the space station's debris is approximately one million times less than the odds of winning a Powerball jackpot. Additionally, there have been no recorded incidents of anyone on Earth ever being struck by space debris. Everyone hopes this record is maintained while what is remaining of Tiangong-1 comes home.

Food for thought — could orbital debris be "***weaponized***?" Certainly worthy of consideration… give a significant piece of orbiting debris or a significantly-sized meteoroid a "nudge" in the correct direction, following careful calculations, and the impact upon a target in space would be similar to that of a missile strike — quite significant.

Works in Progress

Several companies around the world are developing advanced space defense capabilities for defense and offense — all of the words and all of the treaties pale into insignificance when learning of the capabilities and power of who can do what to whom in space… and when.

Over the past couple of years, the U.S. and her allies are starting to realize the dangers inherent in ignoring the threat of ASATs and debris, while aggressor states continue their advancements in these crucial areas of space control... being late to these endeavors could well be deadly.

As U.S. President Trump stated during his 2018 State of the Union address, "*In confronting these dangers, we know that weakness is the surest path to conflict, and unmatched power is the surest means of our defense.*"

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SPACE FOUNDATION'S 2017 SPACE REPORT

The authoritative guide to global space activity — an overview...

Although it is often apparent when changes are on the horizon, their exact nature can be difficult to discern. For the space industry, a clearer picture of the impending changes began to form in 2016. These include the use of cheaper spacecraft in larger numbers, lower-cost launches, the democratization of space, and the exploration of new space-related industries that go beyond the acquisition and transmission of data.

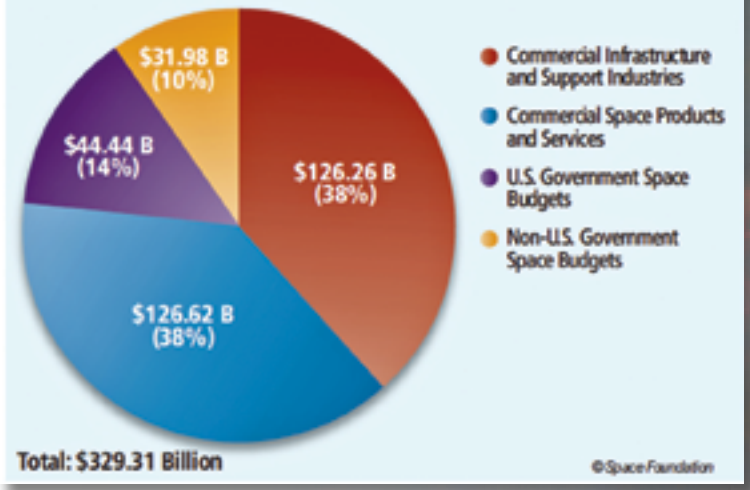
Some of these changes were suggested by dramatic events. A nation that was once the foremost space launch provider fell to nearly half its typical launch rate in 2016 and suffered losses in infrastructure reliability and talent. Launch companies that were once considered premiere space industry mainstays endured job and business losses.

Other changes, while no less significant, unfolded more subtly. Space products and services have become increasingly important to non-space businesses, prompting growth in data products enabled by smaller satellites and less demand for large-scale infrastructure.

The ways in which space products and services are produced and used are changing, and the industry is adjusting accordingly.

1.0 | The Space Economy

Exhibit 1. The Global Space Economy, 2016



The global space industry grew in 2016, reaching $329 billion, up from $323 billion in 2015. Although changes in currency exchange rates once again had a negative impact on non-U.S. revenues as they were converted to U.S. dollars, the effect was substantially less than in 2015, when the total value of the space economy appeared to decline due to large shifts in exchange rates.

In 2016, revenues from commercial sectors continued to represent slightly more than three-quarters of all global economic activity in space. Commercial space products and services—including telecommunications, broadcasting, and Earth observation—constituted the largest sector at $126.62 billion in 2016, essentially unchanged from the year before.

Commercial infrastructure and support industries—including the manufacture of spacecraft, in-space platforms, and ground equipment, as well as launch services and insurance—totaled $126.26 billion in 2016, a 5.3 percent increase.

Global government space budgets declined by 0.3 percent in 2016, as spending totaled $76.43 billion. Government spending accounted for 23 percent of the global space economy, remaining unchanged from 2015.

The U.S. government spent $44.44 billion on defense and non-defense space efforts in 2016, a 0.3 percent decrease from 2015. Non-U.S. government space investment declined by 0.4 percent in dollar terms, primarily due to exchange rates, to a total of $31.98 billion in 2016. In reality, most countries increased their budgets for space activities.

2.0 | Space Infrastructure

For a long period of space history, competitive governmental efforts drove the creation of infrastructure. During 2016, this trend changed as global demand for commercial space-derived products from various space missions increased. Expanding capabilities installed on smaller, significantly less expensive satellites interested more businesses.

These small satellites significantly contributed to growth in data products, which other companies used to create more space-based products and services. Although these smaller satellites were cheaper to build while incorporating acceptable risk, the required launch infrastructure remained relatively expensive until 2016 due to a slow launch tempo and its associated uncertainty and general service costs

In 2016, two U.S. companies continued to launch—then land—space launch vehicles. While the full consequences of reusability have not been explored, grudging price responses from other companies seemed encouraging. From pricing disclosures on new websites to announcements of launch intentions from newer and smaller launch providers, competition started to chip away at launch prices during 2016.

Satellite numbers continued to increase during 2016, with remote-sensing satellite deployments more than twice outnumbering deployments of the next most-popular satellite category. At the same time, discussions were underway to orbit constellations of thousands of broadband communications satellites, spurred by an ever-increasing demand for ubiquitous data availability.

This potential change from fewer than two thousand satellites orbiting the Earth in 2016 to possibly several thousand energized a drumbeat of concern regarding space debris, satellite collision avoidance, and space situational awareness.

One stakeholder, the United States Air Force, has long maintained and updated a publicly available catalog of space objects orbiting the Earth. To supplement this resource, commercial space situational awareness providers grew in membership and customers as more interests and businesses moved into space.

3.0 | Workforce

Although the space economy grew in 2016, with increases in productivity and space products and services, the space workforce for some of the major space industry actors experienced minimal gains, if any, during 2015 (the most recent full year for which data is available).

Through 2015, the U.S. space workforce continued its decade-long contraction, and the Indian space workforce also declined. The European and Japanese space workforces expanded slightly during the same time span. These workforce trends appear to be driven at least partly by newer manufacturing processes.

The nature of the work in the space industry is changing, and it remains to be seen how the technological changes will ultimately affect the size of the workforce. Private companies in the space industry have adopted advanced manufacturing techniques designed to increase productivity, and one probable consequence is a reduced need for low-end production employment.

However, there remains high competition for skilled space industry workers, whose average yearly salaries in the U.S. continue to exceed $100,000.

4.0 | Space Products and Services

Space products and services continued to change the way people do business on Earth. In 2016, satellite data proved invaluable to businesses seeking to gather more meaningful and relevant information in compressed time frames

People and organizations also combined multiple sources of satellite data and services, drawing on expertise in analysis, networking, software development, and other fields to produce meaningful products focused on specific market needs. The resulting products and services drove interest and investment in the global space economy and infrastructure.

For example, these products and services aided agriculture, meteorology, environmental monitoring, and communications. California grape growers and other farmers could buy space products and services that provided detailed reports of crop health. Meteorologists used Global Positioning System (GPS) satellite radio waves to better understand disastrous weather patterns.

The steady integration of terrestrial communications networks and equipment with space products and services provided a means of monitoring vehicle emissions. Some space products could also be integrated with terrestrial equipment, such as tractors or unmanned aerial vehicles, and in some cases, vehicles themselves could be integrated into the space communications infrastructure, providing broadband services to a data-hungry public.

An invitation from the Space Foundation

Since the first edition of *The Space Report* was published in 2006, the Space Foundation research team has gathered an everexpanding collection of information about the space industry, government policies and priorities, and the evolving trends that influence space activity.

Each year, we present the highlights in The Space Report, focusing on the points that we believe are of greatest interest to a broad audience. To further address our readers' research needs, we introduced a new format in 2015— an online service that provides subscribers with access to all the research conducted for The Space Report throughout its existence, as well as new data sets that have never appeared in the report.

We appreciate the positive response to this valuable resource, and we are expanding the types of data we offer in response to requests from our readers. To view more information about this new service, please visit ***www.TheSpaceReport.org***.

SPACE FOUNDATION THE SPACE REPORT

Note: The data contained in the 2017 Space report is derived from 2016 statistics.

Upcoming is the Space Foundation's ***34th Space Symposium***, conducted in Colorado Springs, Colorado. Now in its 34th year, the Space Symposium has come a very long way. The inaugural event saw some 250 space enthusiasts gathered in a single meeting room at The Broadmoor. This year will see the largest number of exhibitors in its 34 year history, with nearly 200 exhibits in the Ball Aerospace Exhibit Hall and expanded Pavilion.

The 34th Space Symposium kicks off on Monday, April 16, 2018, in the International Center of The Broadmoor with the Opening Ceremonies. Several prestigious Space Foundation awards will be presented to individuals and organizations to mark their phenomenal space-related achievements.

To learn more about the Space Symposium, and to register for this event, please access ***www.spacesymposium.org/.***

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