SATCOM For Net-Centric Warfare — March 2017

MilsatMagazine

GREAT EXPECTATIONS

THE LAUNCH OF NROL-79

Cover photo of the Atlas V launch vehicle ready for lift off with the NROL-79 payload is courtesy of United Launch Alliance.

Cover photo is courtesy of Newtec.


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A MYSTERY MISSION LAUNCH BY ULA FOR NRO

All systems were go—and that's just what occurred when the launch vehicle and satellite went up on a ULA Atlas V rocket on Wednesday, March 1, at 9:49:51 a.m. PST, from Space Launch Complex-3 at Vandenberg Air Force Base in California on a mission for the National Reconnaissance Office (NRO).

Aerojet-Rocketdyne's propulsion systems on the Atlas V included the RL10C-1 upper-stage engine, six helium pressurization tanks, and 12 Centaur upper-stage Reaction Control System (RCS) thrusters. The RL10C-1 delivered 22,890 pounds of thrust to power the Atlas V upper stage, using cryogenic liquid hydrogen and liquid oxygen propellants.

Despite several delays of this launch dating back to January 16, in which an issue involving the second stage of the Atlas V launch vehicle was revealed, such was no longer a challenge for the launch that took place aboard a United Launch Alliance Atlas V 401 basic configuration rocket.

What is the NRO? When the United States needs eyes and ears in critical places where no human can reach—be such over the most rugged terrain or through the utmost hostile territory—the government turns to the National Reconnaissance Office (NRO) for their expertise.

The NRO is the US Government agency in charge of designing, building, launching, and maintaining America's intelligence satellites. Whether developing the latest innovations in satellite technology, contracting with the most cost-efficient industrial supplier, conducting rigorous launch schedules, or providing the highest-quality products to customers, the agency never loses focus—the agency works to protect the US and the nation's citizens.

From inception in 1961 to declassification to the public in 1992, the NRO works to provide the best reconnaissance support possible to the Intelligence Community (IC) and Department of Defense (DoD).

The primary mission is to advance and shape the Intelligence Community's understanding of the discipline, practice, and history of national reconnaissance. The objective is to ensure that NRO Leadership has the analytical framework and historical context to make effective policy and programmatic decisions.

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#2	25,000 lbf	3" Stroke
#3	20,000 lbf	2" Stroke

Model R16C		
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#2	13,000 lbf	2" Stroke

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"I am so impressed by the incredible teamwork between the NRO, US Air Force, our industry partners and the ULA team that resulted in today's successful launch. The integrated mission team overcame many challenges, including delays associated with the Vandenberg Canyon Fire last year," said Laura Maginnis, Vice President, Government Satellite Launch for ULA. "Tragically, Ventura County firefighter Ryan Osler lost his life en route to assist in fighting the fire. We are honored to dedicate today's mission to Ryan and his family. Thank you to all of the men and women who worked to deliver this critical asset for our nation's security."

This mission, launched aboard an Atlas V Evolved Expendable Launch Vehicle (EELV) 401 configuration vehicle, included a four meter in diameter extended payload fairing. The Atlas booster for this mission was powered by the RD AMROSS RD-180 engine and the Centaur upper stage was supplied by the Aerojet Rocketdyne RL10C-1 engine.

This is ULA's second launch of 2017 and the 117th successful launch since the company was formed in December of 2006. ULA's next launch is the Delta IV WGS-9 satellite for the US Air Force. The launch is scheduled for March 8 from Space Launch Complex-37 at Cape Canaveral Air Force Station, Florida.

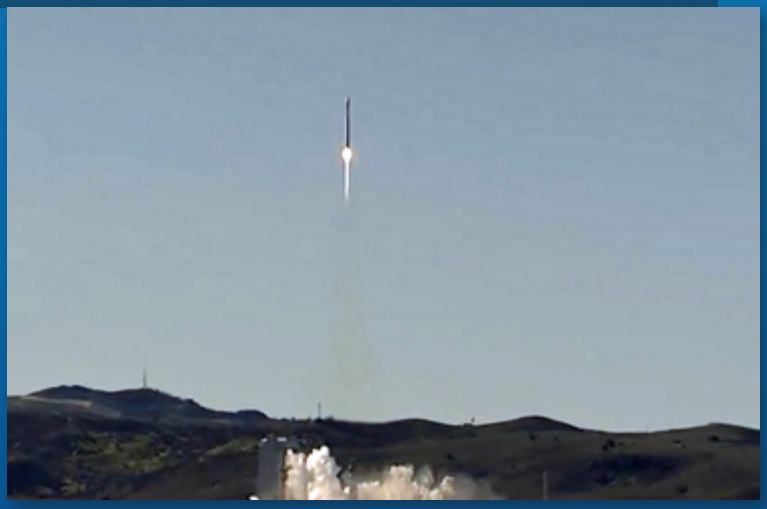
The EELV program was established by the US Air Force to provide assured access to space for DoD and other government payloads. The commercially developed EELV program supports the full range of government mission requirements, while delivering on schedule, and providing significant cost savings of the heritage launch systems.

ULA has successfully delivered more than 115 satellites to orbit that provide critical capabilities for troops in the field, aid meteorologists in tracking severe weather, enable personal device-based GPS navigation and unlock the mysteries of our solar system.

A huge effort is required to lift these vehicles into space and such an accomplishment for the ULA Atlas V rocket is highly dependent upon the RD-180 engine. The Russian RD-180 main engine delivers more than 860,000 lbs of thrust at liftoff and an impressive range of continuous throttling capability, a main engine that is a powerful combination of innovation and performance. Designed and manufactured by NPO Energomash, the liquid oxygen/liquid kerosene, two-thrust-chamber RD-180 engine is a complete propulsion unit equipped with hydraulics for control valve actuation and thrust vector gimbaling, pneumatics for valve actuation and system purging, and a thrust frame to distribute loads.

The rocket, an Atlas V 400, is part of the Atlas V family, which includes the Atlas V 400 and 500 series, and is the latest evolutionary version of the Atlas launch system. Atlas V uses a standard common core booster™ (CCB), up to five strap-on solid rocket boosters (SRB), an upper-stage Centaur in either the Single-Engine Centaur (SEC) or the Dual-Engine Centaur (DEC) configuration, and one of several payload fairings (PLF). A three-digit (XYZ) naming convention is used for the Atlas V 400 and 500 series. The Atlas V 400 series incorporates the flight proven, 4 meter in diameter, 12.0 meter (39.3 ft) large payload fairing (LPF), the 12.9 meter (42.3 ft) extended payload fairing (EPF), or the 13.8 meter (45.3 ft) extended EPF (XEPF).

Launch images are courtesy of United Launch Alliance.



DISPATCHES

DISPATCHES

Compelling New Features Abound with Spectra Group's Slingshot

Spectra Group UK has further enhanced its innovative SlingShot® product by unveiling new features that are destined to enhance the product's growing popularity as a key asset in the modern battlefield.

Recently referred to by a specialist user as "a game-changer," SlingShot converts in-service VHF and UHF tactical radios to L-band for robust, reliable and cost-effective Beyond Line of Sight (BLOS) Communications on the Move (COTM), using Inmarsat's L-TAC™ satellite service.

With the ability to extend the secure net over thousands of miles, to connect dismounted, mounted and air and seaborne personnel to each other and to HQ, the already flexible system has been further improved with new power options and the launch of the SlingShot TLT (Test Loop Translator), an L-Band emulator for full offline system testing without a live satellite channel.

SlingShot's new power options deliver increased flexibility and even simpler configuration making deployment planning and set-up even easier.

The new power upgrade introduces a universal power supply—UPSU—that streamlines the system, with more flexible power supply options and intelligent power delivery plus an enhanced troubleshooting light reporting system. There is also now available an AA battery cassette to power a full manpack system.

The reasons for opting for SlingShot's new power options are compelling...

- *Simplified deployment planning when using SlingShot*
- *Accelerated configuration with enhanced troubleshooting*
- *Reduced weight of back-up power using the AA battery case*
- *Increased flexibility being able to use AA batteries for manpack and UPSU for any system*

spectra-group.co.uk/

FEATURES

ADVERTISER INDEX

DISPATCHES

iDirect Government launches satellite routers for airborne missions

iDirect Government (iDirectGov) had debuted their high-speed 9-Series Airborne Satellite Remotes which will provide enhanced functionality in a variety of form factors to enable government organizations to use the best options for military missions.

Whether coordinating with ground elements, transmitting high-definition intelligence, surveillance and reconnaissance (ISR) video or conducting inflight mission planning, the 9-Series airborne product line is fast, secure and efficient. The 9-Series, which includes the 980 Airborne Satellite Router Board, the 9800 AE (ARINC 600 enclosure) and the 9800 AR (1RU enclosure), delivers as much as 45 Msps downstream and as much as 29 Msps upstream. These products incorporate transmission security (TRANSEC),

designed to meet Federal Information Processing Standards (FIPS) 140-2 Level 3 and AES 256-bit link encryption standards.

The Airborne Satellite Routers are compatible beginning with iDirect Evolution and Velocity 1.3. They incorporate the OpenAMIP standard, which gives users the ability to select a variety of airborne antenna systems for their missions. The Airborne Satellite Routers range from 3 pounds to 17 pounds and encompass dimensions ranging from 4.88 inches wide, 15.03 inches deep and 7.62 inches tall to 19 inches wide, 21 inches deep and 1.73 inches tall. Additional features include:

- *Dual demodulators for make-before-break connectivity*
- *TRANSEC zeroize capability*
- *Built-in automatic uplink power*
- *Frequency and timing control*
- *Over-the-Air Security X.509 authentication*
- *Open antenna modem interface protocol (OpenAMIP)*
- *Ultra-high-speed communications*

www.idirectgov.com/

DISPATCHES

Threat Mitigation Training by USAF

The 26th Space Aggressor Squadron at Schriever Air Force Base is always gearing up for the next exercise in replicating enemy action against space-based and space-enabled systems.

Teams of adversary subject matter experts regularly employ jamming techniques to train Air Force, joint and coalition personnel how to recognize, mitigate, counter and defeat threats.

"*Our mission is to train others*," said Senior Master Sgt. Benjamin Millspaugh, the 26th SAS superintendent. "*Currently, Schriever is the only place in the Department of Defense that provides this type of instruction and training that we use to help get our military partners up to speed.*"

The squadron acts like a consultant, teaching its clients how to navigate a world full of noise. The world being space, and the noise being rivals that want to prevent their communications or steal information.

Acting as the "bad guy," space aggressors deny operators use of their capabilities like GPS and SATCOM in order to train warfighters how to operate in environments where critical systems are interfered with or completely negated.

To do this, space aggressors replicate adversary systems to provide a threat representative affect the United States' joint and allied forces. They use a variety of hardware in creative ways to ensure the antennas, amplifiers, and additional hardware are used in the same way an adversary would employ them.

Additionally, they build waveforms that match GPS signals coming down to jam and knock receivers off the GPS signal. They perform various operational configurations and set up multiple antenna sites just like an adversary.

Millspaugh compared the ability to discern and understand another's data to talking louder than others. If you want to be heard, you make your voice stand out. The space aggressors stand out by projecting more power or getting closer to the target in order to transmit their signal and block others.

To successfully interfere: frequency, access and power are needed. SATCOM has many frequencies and can access a signal from a far distance. The traditional SATCOM satellite can see one-third of the Earth, from 22,300 miles away in its geosynchronous orbit. However, GPS is in a completely different orbit and uses various frequencies to update the position, navigation and timing for systems all over the world.

The space aggressors target two frequencies—L1 and L2—from the ground—they need to be local in order to accurately affect the training audiences' receivers, otherwise it will affect all signals within range and interfere with entities not participating in the exercise.

The team spends 200 days a year training others how to combat this interference. Setting up an exercise can take up to six months with all of the internal checks and third-party verifications to ensure they're only affecting signals they're authorized to. Notifications are also made to the Federal Aviation Administration, commercial airlines, and the maritime community a few weeks out to make them aware of the exercises.

"*The United States Air Force Warfare Center decides which exercises to conduct, and the squadron maintains operational flexibility to cater to our client's needs*," Millspaugh said. "*Then we determine the level and type of interference based on the client's capabilities; it's like referring to a play book.*"

One of the exercises the squadron supports is Red Flag, which takes place at Nellis AFB, Nevada, multiple times per year. Their SATCOM is run from Schriever AFB, but the GPS function happens at Nellis AFB since the jamming needs to be localized.

The 26th SAS has been training troops since World War I. It is the oldest squadron in the Air Force Reserve and one of the oldest in the Air Force. It was inactivated after the Cold War, but was reactivated at Schriever AFB in 2003 when the Air Force recognized a need for aggressors. The unit was realigned under Nellis AFB's 926th Operations Group in 2008.

Story by Maj. Jessica D'Ambrosio, 926th Wing Public Affairs, USAF.

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DISPATCHES

BMC2 Capabilities Must Evolve to Meet the Challenges of Operating in Space

Space is becoming a warfighting domain and Air Force Space Command's operations and warfighting culture must evolve rapidly to meet the challenges of operating in the contested, degraded and operationally limited (CDO) space domain

The expectation is that US space systems will face an increasingly wide range of man-made threats in the next 20 years capable of causing both reversible and irreversible effects. To fight through the increasingly complex environment with growing and increasingly diverse threats, we will continue to improve the mission assurance of our space capabilities by developing multi-domain defensive systems and responsive tactics, techniques, and procedures.

USAF Battle Management Command and Control (BMC2) capabilities must evolve because today's C2 functions, infrastructure, organization and training do not yet deliver the real-time capability commanders need to synchronize execution and fight on tactical timelines. The response to threats must be agile and ensure AFSPC's organize, train, and equip (OT&E) activities are informed by well-documented and clear authorities, roles, responsibilities, command relationships and warfighting requirements.

This increasingly hostile space threat environment means that a space warfighting force must be capable of deterring or fighting through adversary actions to deliver required space effects in support of the Combatant Commander.

The AFSPC commander's Space Enterprise Vision identified the development and employment of a BMC2 system as a foundational pillar to transforming the space mission enterprise to meet future challenges.

A BMC2 system with the capability to manage the fight on tactical timelines is one of several ongoing AFSPC efforts aimed at integrating a warfighting mentality into space mission operations and creating a space mission force construct.

Story by By Lt. Michael Shenk, Los Angeles Air Force Base, Air Force Space Command

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DISPATCHES

Kratos' New Ground Station Capabilities

A specialized National Security technology company that provides mission critical products, solutions and services for the US, Kratos Defense & Security Solutions, Inc., has announced they have developed new ground system capabilities to help operators respond to a changing satellite environment.

VSATs bring new challenges and complexities to signal monitoring. A major challenge is that VSAT terminals operate in TDMA mode where many terminals share the same frequencies making it virtually impossible to determine which terminals are causing the interference. Among the new solutions the firm offers...

- ***Ending VSAT Interference***
  New technology from Kratos enables operators to scan, identify, locate and resolve VSAT generated interference in minutes.

- ***Optimizing Gateways***
  Dramatic growth in satellites and throughput are driving changes to gateway design and management.

- ***Spot Beam Monitoring***
  Kratos' new approaches to ground system design, operations management and antennas can help operators reduce CapEx and OpEx. Hundreds of spot beams from hundreds of HTS require a new approach to beam monitoring.

The solutions are all part of Monics 200, a fully-featured, cost-effective sensor for High Throughput Satellite (HTS) spot beam monitoring that can be cost-effectively integrated back to a central monitoring center.

kratoscomms.com/

DISPATCHES

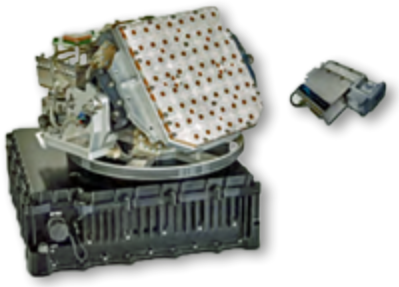
The SATCOM Needs of UAS Addressed by Gilat with a New Terminal

The growth and use of Unmanned Aircraft Systems (UAS) continues to create new opportunities for businesses involved in the SATCOM arena, such as Gilat Satellite Networks Ltd.—the firm has just made commercially available their ultra-compact airborne SATCOM terminal for UAS.

Tactical, long-endurance UAS are commonly used to gather and send intelligence, surveillance, and reconnaissance (ISR) information to ground stations in real time.

Reliable, high-performance satellite communications are crucial for ensuring uninterrupted broadband connectivity in beyond line-of-sight (BLOS) missions.

The newest in Gilat's field-proven family of unmanned aerial terminals—BlackRay 72Ka—combines high performance and throughput



with a minimal footprint. Weighing less than 5 kg (11lbs.), the compact BlackRay 72Ka terminal is an ideal solution for even very small-unmanned aerial vehicles (UAVs).

The miniature BlackRay 72Ka is specifically designed to operate with the new generation of Ka-band HTS and supports data speeds of up to 2 Mbps for any IP-based voice, video or data BLoS application. This highly integrated terminal comprises best-of-breed VSAT technologies developed and manufactured by Gilat.

The BlackRay 72Ka terminal provides full-duplex SATCOM, linking the UAS to its ground control station. The forward link provides command and control capabilities, while the return link transfers sensor data.

This new BlackRay 72Ka terminal addresses the tactical need for reduced size and weight, helping to increase mission effectiveness. The system's tiny dimensions enable BLoS operations for the smallest UAS platforms, with remarkable data speeds needed to support real-time downloads of high resolution images.

gilat.com/

DISPATCHES

Hughes DISA Wins General Atomics SATCOM Contract for SkyGuardian™

The Defense and Intelligence Systems Division (DISD: *defense.hughes.com/*) of Hughes Network Systems, LLC (HUGHES) has reported that they have been awarded a contract by General Atomics Aeronautical Systems, Inc. (GA-ASI).

Hughes will work with GA-ASI to provide SATCOM on the "Type-Certifiable" Predator® B (TCPB) Remotely Piloted Aircraft (RPA) system, which provides the basis for the United Kingdom's Protector program. A variant of the proven multi-mission Predator B, the new SkyGuardian™ aircraft will provide a next-generation capability, integrating enhanced safety and reliability systems that will enable RPA flight within civilian airspace, along with an increased payload capacity that will support a wide variety of mission sets.

Working with GA-ASI, Hughes is upgrading the aircraft's SATCOM system with customized airborne Hughes HM series modems. The advanced modems will enable a significant increase in data transfer rates, employing an enhanced waveform that ensures resilient and secure communications when operating in challenging environments.

The new aircraft is designed to be compliant with NATO and UK airworthiness requirements, supporting easy integration into segregated and non-segregated civil airspace operations around the world. The SkyGuardian RPA expects to meet initial European certification standards this year.

Rick Lober, the Vice President and General Manager of Hughes DISD, stated that with the development and supply of the firm's customized HM series modem, aircraft operators and mission personnel will experience the benefits of protected SATCOM, which includes the flexibility to employ the most appropriate frequencies for Beyond-Line-of-Sight (BLoS) communication.

defense.hughes.com/

DISPATCHES

Harris—This Falcon Flies... and Brings Battlefield Techniques to IDEX, Keeping Soldiers Connected

The RF-300H is the market's only standalone solution for Beyond-Line-Of-Sight (BLOS)communications in the absence of satellite.

This wideband system is the only HF manpack meeting new NSA crypto-modernization standards.

Harris now offers the smallest, lightest and fastest wideband manpack radio that is fully backwards compatible with the Harris Falcon II HF product line, with more than 100,000 radio units deployed worldwide.

Harris Corporation revealed the Falcon III® RF-300H ,which dramatically improves HF tactical communications by transmitting high-level security images, maps and other large data files from beyond-line-of-sight environments in a compact, lightweight package.

The RF-300H manpack from Harris replaces the US Type 1 AN/PRC-150(C) and delivers data up to 10 times faster in a package that is 20 percent smaller and lighter.

The unit provides a reliable alternative to satellite communications for BLOSvoice and data communications and also features either a commercial GPS or a Selective Availability Anti-Spoofing Module (SAASM).

Chris Young, president, Harris Communication Systems stated that the RF-300H delivers an advanced solution for warfighters facing today's complex environment, and provides more security and enhanced wideband HF than any other radio in the marketplace.

At the 2017 International Defence Exhibition and Conference (IDEX) in Abu Dhabi, UAE, Harris Corporation displayed a large assortment of products and integrated systems to help military customers connect with the battlefield.

These solutions meet urgent security challenges associated with intelligence, surveillance and reconnaissance (ISR) issues and provide opportunities for modernizing force structures.

Harris offers fully integrated solutions, with offerings such as digital command and control, tactical communications, persistent surveillance,

night vision, robotics and more. Solutions that will be showcased include:

Harris hC2T Software Suite Command
A complete command and control solution that connects all echelons and provides a common operational view with real-time intelligence.

Harris Falcon III® RF-7850A-MR Multi-channel Airborne Networking Radio
World's first certified airborne two-channel networking radio extends ground tactical capabilities to the aerial tier.

Harris Falcon III® RF-7850M-HH Multiband Networking Handheld Radio
Delivers the power and performance of a manpack in a ruggedized, SWaP-friendly handheld radio.

Harris Falcon III® RF-7850M-V51x Vehicular/ Base Multiband Radio System
System provides superior Combat Net Radio performance and flexibility.

BeOn® Secure Group Communications Application
Secure group-communications app that enables Push-to-Talk (PTT) and real-time location and presence information.

CorvusEye
Wide Area Motion Imagery (WAMI) system helps users monitor activity, track movement, and gather critical intelligence over a city-size area.

T7 Robotic Explosive Ordnance Disposal (EOD) System
Robot features intuitive control and human-like dexterity - making it easy to complete complex tasks with minimal training time.

harris.com/idexuae.ae

DISPATCHES

Military UAV Market 2016 to 2018 Published by Orbis Research

The Global Military UAV Market will be driven by internal and external security threats, territorial disputes, and modernization initiatives undertaken by armed forces across the world. Significant UAV customers include countries in the North American and Asia Pacific region, and the global UAV market will be dominated by the US throughout the forecast period.

Asia Pacific's share of the global UAV market is also projected to increase, largely due to a number of international territorial conflicts and insurgency issues.

Key findings include...

- *The global military UAV market values US$8.5 billion in 2016, and is expected to grow at a CAGR of 4.89 percent, to value US$13.7 billion by 2026*
- *North America is projected to dominate the market with a share of 32 percent over the forecast period, followed Europe at 31 percent, and Asia Pacific at 30 percent. The Middle Eastern market for UAVs is expected to account for a share of 4 percent, followed by the Latin American and African markets with a cumulative share of 2 percent*
- *HALE UAVs and UCAVs are expected to account for 34 percent and 29 percent of the global military UAV market respectively, followed by MALE UAVs, TUAVs, VTOL-UAVs, and MUAVs, with respective shares of 19 percent, 9 percent, 6 percent and 3 percent.*

The Global Military UAV Market 2016-2026 report offers a detailed analysis of the industry, with market size forecasts covering the next ten years and the inluences for military UAVs and key market trends.

In-depth analysis includes..

- *Market size and drivers: detailed analysis during 2016-2026, including highlights of the demand drivers and growth stimulators. It also provides a snapshot of the spending and modernization patterns of different regions around the world.*
- *Recent developments and industry challenges: insights into technological developments and a detailed analysis of the changing preferences of military UAV segments around the world. It also provides trends of the changing industry structure and the challenges faced by industry participants.*
- *Regional highlights: study of the key markets in each region*
- *Details of the key programs in each segment, which are expected to be executed during 2016-2026.*
- *Competitive landscape and strategic insights: analysis of the competitive landscape of the global market. It provides an overview of key players, together with information regarding key alliances, strategic initiatives, and financial analysis.*

orbisresearch.com/reports/index/the-global-military-uav-market-2016-2026

DISPATCHES

US Defence Agency Orders Norsat's GLOBETrekker 2.0 Terminals

Norsat International Inc. has received an approximate $3.3 million order for their GLOBETrekker 2.0 portable satellite terminals from a US Combat Support Agency supporting the US Department of Defense and Intelligence Community.

The GLOBETrekker 2.0 is an intelligent fly-away satellite terminal with unsurpassed reliability, advanced auto-acquire technology, and a flexible deployment platform.

A simple one touch interface and the LinkControl™ software allow for automatic satellite acquisition so less experienced operators can easily use the system while multi-tasking on other field operations setup tasks.

These military-grade, auto-acquire terminals will provide:

» *Dual-band (X- and Ku-band) connectivity to ensure access worldwide depending on the satellite and bandwidth available in the area of deployment*

» *An integrated optic module to link the Outdoor Unit (ODU) to an Indoor Unit (IDU) modem over great distance without added weight*

» *The ability to quickly and easily change the RF equipment which makes the GLOBETrekker very adaptable to meet the changing requirements of the customer*

The customer, who has worked with Norsat previously, selected the GLOBETrekker 2.0 terminal due to the functionality of our built in spectrum analyzer, the ruggedness of the unit, the sunlight readable display and LinkControl profile which makes the system very easy to use.

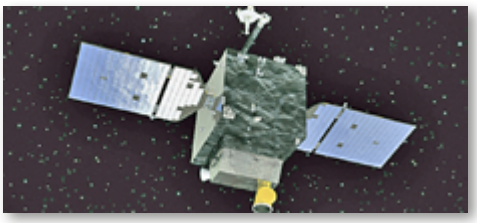
Norsat expects to start the shipments of the terminals during the 1st half of 2017.

norsat.com/product/globetrekker/

DISPATCHES

Orbital ATK's New Involvement with USAF's STPSat-6

Orbital ATK has been awarded a contract by the US Air Force Space and Missiles Systems Center to provide payload integration and support services for Space Test Program Satellite 6 (STPSat-6).



Artistic rendition of the STPSat-6 satellite.

The multipurpose satellite will operationally demonstrate advanced communication capabilities, collect space weather data and support nuclear detonation detection in the Earth's atmosphere or in near space. STPSat-6 is the primary payload on the STP-3 mission which is set to launch no earlier than June 2019.

STPSat-6 will be built on an Orbital ATK satellite bus that will be modified to fit mission requirements. Under the contract, Orbital ATK will integrate and test the spacecraft, deliver operations procedures, and support launch and on-orbit check-out. The satellite will carry nine payloads from the Department of Defense, National Nuclear Security Administration and NASA.

The multiple payloads on board STPSat-6 include the Space and Atmospheric Burst Reporting System (SABRS-3), NASA's Laser Communication Relay Demonstration (LCRD), and seven experiments from the DOD Space Experiments Review Board. Orbital ATK's heritage bus and avionics product line is designed to support multiple payloads and can be adapted to support the customer's desired mission life.

The STP-3 mission is sponsored and managed by the Space Test Program (STP), which is the primary provider of spaceflight for the United States Department of Defense (DOD) space science and technology community. STP is managed by the Advanced Systems and Development Directorate of the Space and Missile Center.

Chris Long, the Vice President of National Space Systems at Orbital ATK, noted that this flexible and modular satellite bus platform provides an especially unique opportunity to host multiple instruments from three departments of government on one spacecraft, achieving customer goals at an affordable price.

orbitalatk.com/

USHERING IN THE NEW GENERATION OF HIGH THROUGHPUT SATELLITES (HTS)

By Tony Bardo, Assistant Vice President, Government Markets, Hughes, and Senior Contributor

At the start of this 21st century, exploding demand for all things Internet fueled the corresponding response of the tech industry in the form of new devices, networks and services to keep us connected, all of which generated a tsunami of social and economic change that continues unabated today.

Indeed, fundamental new ground was broken when Hughes first introduced high-speed satellite Internet access to the consumer marketplace in North America—connecting homes and businesses either unserved or underserved by terrestrial or wireless providers, an addressable market estimated to exceed 10 Million in the US alone.

Though many then considered this to be a flawed strategy, this bold direction has exceeded the company's expectations, as Hughes now serves more than one million subscribers and the company's consumer business is growing at double-digit rates.

Powered by successive generations of broadband satellite technologies, this growth has been built upon the company's success for more than 30 years supplying satellite broadband to hundreds of thousands of enterprises across virtually all verticals—from retail, oil/gas, to hospitality and automotive.

Not surprisingly, Hughes has now leveraged commercial satellite technology to expand its presence in the government marketplace—powering a wide range of solutions for agencies in all spheres of public service, from connecting park stations to implementing secure, online training networks. Recent advances in high-throughput satellite technology—as evidenced by the successful launch in December of EchoStar XIX, the world's largest capacity communications satellite—have positioned Hughes to ramp up the game with the next-generation of satellite Internet service, and in so doing open up significant new possibilities for the public sector.

INTRODUCING THE NEW ECHOSTAR XIX SATELLITE

Designed with Hughes JUPITER™ System technology, EchoStar XIX is a multi-spot beam, Ka-band satellite that will power the new HughesNet® Gen5 service, with speeds faster than many DSL plans.

Capable of delivering 100 Mbps downloads to individual, pizza-sized VSAT terminals at customer premises, this isn't our grandparents'—or even our parents'—satellite service. Combined with the capacity of the company's existing broadband satellites, EchoStar XVII and Spaceway 3, Hughes will soon have more than 300 Gbps capacity to serve the growing subscriber base across North America, offering a range of plans to suit any budget. If any further validation were even needed, the Federal Communications Commission (FCC) in their *2016 Broadband in America* report ranked HughesNet Gen4 #1 in delivering advertised speeds—for the second year in a row.

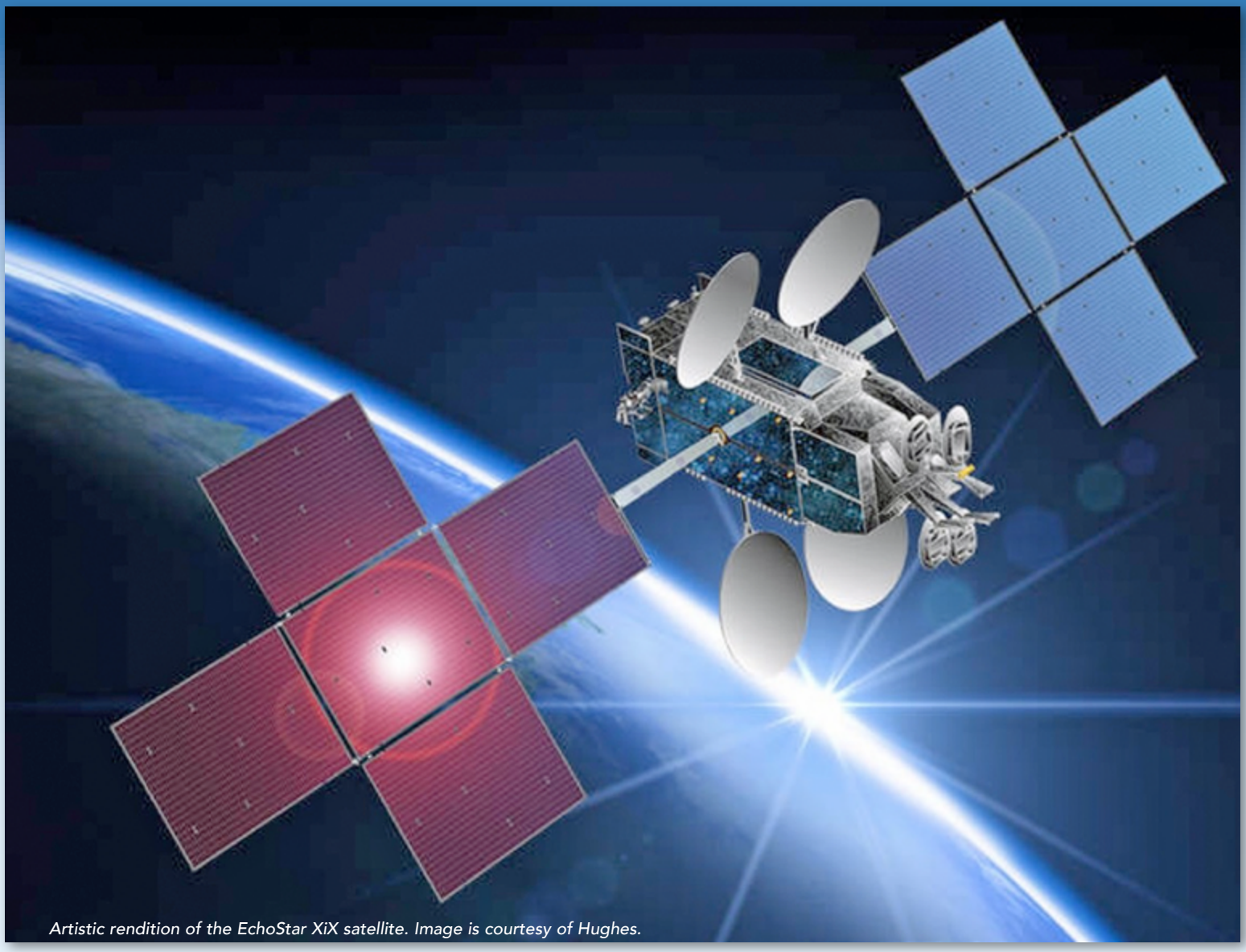
This translates into more speed, more data and more advanced features, such as enhanced security for the many different applications of federal, state and local governments. With coverage from coast-to-coast, Hughes will offer its service and solutions to the government via a number of different contract vehicles.

BACKING UP CRITICAL TERRESTRIAL NETWORKS

One major initiative underway today in the US is the adoption of next-generation 9-1-1 (NG9-1-1) systems. Many Public Safety Answering Points (PSAPs), locations that house 9-1-1 operators, still can't receive text messages, let alone pictures or video.

With the adoption of NG9-1-1 architectures, PSAPs will immediately benefit from capabilities such as text-to-9-1-1, image and video communications, accurate cellular caller location, more efficient call routing, and the ability to group related calls together for a coordinated response.

Given the importance of keeping emergency services always online and ready to respond, PSAPs adopting NG9-1-1 technology are quickly realizing that they cannot depend on single-threaded connectivity paths in and out of their network sites. To protect themselves from the major risk of a network outage, PSAPs have started to use satellite connectivity as a backup path as satellites alone offer a true alternate path to terrestrial links, which are all vulnerable in the face of natural or man-made disasters. As NG9-1-1 becomes the standard nationwide, administrators are pursuing satellite



Artistic rendition of the EchoStar XiX satellite. Image is courtesy of Hughes.

backup networks because they don't share the vulnerabilities of primary terrestrial network lines and can provide the bandwidth and speed needed to support modern communications.

As a case in point, a council of governments in Texas received a ***GCN DigIT Award*** in 2016 for their implementation of a satellite back-up system from Hughes into their existing 9-1-1 network.

By supporting these networks with advanced capabilities to achieve high availability and security, including QoS, packet compression and acceleration, Hughes satellite solutions present a compelling and cost-effective way to ensure emergency calls go through and appropriate resources are dispatched.

CONNECTIVITY FOR FIRST RESPONDERS

Another important area is the support of first responders on the ground, for whom reliable communications are essential in order to share information and effectively coordinate recovery efforts.

For example, in the aftermath of Hurricane Katrina and Superstorm Sandy, responders relied on both mobile satellite terminals and rapidly installed VSAT stations to remain connected when terrestrial fixed and wireless infrastructure had been damaged and were unusable.

Recognizing the need for turnkey emergency response solutions, Hughes offers fully-managed, cost-effective options, including:

- *Deployable SATCOM systems for disaster recovery with coast-to-coast coverage*
- *Advanced QoS techniques to ensure optimal performance of critical applications*
- *Turnkey network deployment, configuration and implementation*
- *Proactive diagnostic management of equipment and network*

CONNECTIVITY AT THE EDGE

All too often, today's government agencies are forced to make tough decisions that balance decreasing budgets against increasing bandwidth requirements at widely distributed site locations.

The common approach has been to purchase additional dedicated T1 lines, which are expensive and lacking in both bandwidth and scalability. As a result, agencies are paying far too much for technology that does not support their daily requirements.

Instead of stacking multiple, expensive T1 lines on top of one another, government agencies are innovating by adopting a hybrid network model that blends their existing MPLS network with broadband connectivity at distributed sites. Not only is broadband faster than T1, it is also much more cost-effective.

Hybrid networks can make use of satellite broadband to replace or supplement T1 access as well as allow agencies to bring high-speed connectivity where terrestrial last-mile infrastructure cannot always reach.

For remote office connectivity, Hughes offers to:

- *Integrate "last-mile" locations into dedicated networks via hybrid architecture;*
- *Support growing number of connected devices and cloud-based applications;*
- *Deploy broadband to single remote sites like park offices or research locations*

CONNECTING STUDENTS EVERYWHERE

Across the nation, broadband Internet access is often taken for granted. Unfortunately, this is not a luxury that many of our nation's schools possess.

As last-mile infrastructure is too expensive to build out to rural and remote areas, roughly 12 percent of schools still lack quality broadband access, according to Education Superhighway's 2016 ***State of the States Report***. These access limitations prevent some schools from properly administering online testing requirements and in meeting 21st century learning standards. This puts students attending these schools at a competitive disadvantage with their peers around the nation who are being introduced to computer science skills, digital learning, and online resources.

To ensure that every student has the resources they need, underserved schools and districts should consider using next-generation, high-speed satellite Internet. With Hughes, schools can also use the federal E-Rate program to receive reimbursement from the government for as much as 90 percent of the total cost of their Internet service investment. E-Rate reimburses the monthly service costs as well as the hardware and installation expenses.

To assist rural and remote school districts, Hughes offers:

- *Coast-to-coast coverage*
- *Higher speeds and data needed to provide students with a 21st century education*
- *Eligibility for E-Rate reimbursement program*

These are just a handful of ways that the new generation of HTS technology that currently, and will continue, to positively impact the public sector. In striving to meet its mission goals, Hughes will continue to push the innovation envelope to deliver cost-effective solutions for government, connecting people and organizations, improving emergency response coordination and enabling higher quality education for our nation's students.

government.hughes.com/company

Anthony "Tony" Bardo has 20+ years of experience with strategic communication technologies that serve the complex needs of government. Since joining Hughes Network Systems in January 2006, Bardo has served as assistant vice president of Government Solutions, where he is focused on providing Hughes satellite broadband applications solutions to Federal, State, and Local governments. Bardo also recently served as Chair of the Networks and Telecommunications Shared Interest Group (SIG) for the Industry Advisory Council, an advisory body to the American Council for Technology (ACT).

Before joining Hughes, Bardo was with Qwest Government Services for nearly five years where he served as senior director of civilian agencies sales and marketing, senior director of marketing, and senior director of business development. Prior to Qwest, Bardo spent 14 years with the government markets group at MCI where he held the position of executive director for civilian agencies. During his tenure, his teams managed programs with the Federal Aviation Administration's national air traffic control network, the Social Security Administration's toll-free network, the US Postal Service Managed Service Network, and the US General Services Administration's FTS2001.

SECURING A LEGACY

BY UNVEILING THE FUTURE

Introducing M-Series – The Industry's Lightest Wideband Ka Carry-On-Compliant 90cm Antenna

Incorporating over a quarter-century of modularity and precision engineering, DataPath's M-Series is the world's most portable 90cm terminal - capable of fitting in an airline's standard overhead compartment or ship's berth.

In addition to industry leading service and support, DataPath's powerful MaxView® Enterprise™ network monitor and control software comes standard. When bundled with your choice of network, professional or our award-winning Cyber Security services, the M-Series outweighs anything in its class.

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PLAN FOR THE WORST… AND HOPE FOR THE BEST

By Garrett C. Hill, Chief Executive Officer, X2nSat, Inc.

They say hindsight is 20/20—that is the case when evaluating the effectiveness of how prepared a company or government agency was when dealing with a disaster scenario.

The Oroville Dam spillway challenge in Northern California is a solid example of what can occur when too much rain and snow melt occur over just a few days.

Sheriff Kory Honea of Butte County in Northern California decided to evacuate almost 200,000 people from the area of the dam—people who would have been in the immediate path of a 30 foot wall of water if the Oroville Dam had failed.

Listening to his press conference after ordering the evacuation, this was an easy decision for him to make. There was no way he was going to take a chance that many of his friends and neighbors could be subjected to a potentially deadly situation. Perhaps not as devastating as the Tsunami in Malaysia in 2004, but a further dam break could have caused far more loss of life than Hurricane Katrina or any other disaster event in US History.

For the record, let me say that Sheriff Honea and all the other personnel and agencies involved did a fantastic job when they were faced with a potential emergency of epic proportions. With more rain on the way, this is an evolving situation that could quickly become dangerous again.

The Oroville Dam in Northern California during the recent spillway emergency.

This "event" should have gained the attention of many other agencies and organizations around the country and have them thinking "*what if*" in regards to potential disaster scenarios that their communities could be subjected to unexpectedly.

HAVE A PLAN

Companies, organizations and government agencies should have exhaustive, detailed plans for any number of potential threats and natural disaster scenarios. When disaster actually strikes, it is far too late to start a planning session.

In an emergency, equipment and personnel will be stressed and pushed to the maximum. Having a plan allows people to take a deep breath and rely on their training to continue on to the business of saving lives and property. First responders are true heroes. They deserve to have the best leadership and resources to get the job done under the most difficult of situations.

X2NSAT MOBILE COMMAND CENTER

Having the correct equipment available in an emergency toolbox can make all the difference in the world. If there had been a major failure to the spillway or the dam, critical power and communications infrastructure would have been heavily compromised.

X2nSat's emergency response trailers can be quickly deployed to provide satellite connectivity to local, regional, and national wireline numbers as well as act as a repeater for hand-held radio terminals. These portable, self-contained satellite terminals can run continuously for two weeks without refueling and provide a vital link for voice and data communications in emergency scenarios.

TEST THE PLAN

All of us know how the best laid plans in our everyday lives can easily get thrown off-track. One can only imagine all of the possible ways something can go wrong in the middle of a disaster scenario.

Many agencies and communities will hold disaster readiness drills to give all the coordinating resources the opportunity to mobilize and put the plan to the test. This gives all stakeholders an opportunity to identify potential shortfalls in contingency plans and shore them up.

Sheriff Honea and the agencies involved with the Oroville Dam scenario carefully evaluated of how their teams executed as well as how their equipment performed when this major catastrophe loomed in their area of responsibility—they will, no doubt, be even more should a "next time" occur.

UPDATE THE PLAN

Conditions change all the time. Just because you have a great plan that seemed more than adequate three years ago, such does not mean that there are not new threats that need to be accounted for today.

Disaster contingency plans should be updated at least once a year or whenever significant shortcomings in the plan have been identified or when new technology becomes available.

Hope is never a good strategy when trying to protect lives and mitigate the loss of property damage.

There is no substitute for preparedness and the necessity of practicing the execution of a plan and being in possession of the correct tools to adequately respond.

X2nSat has been able to provide many companies and agencies with communications capabilities that perform under the worst disaster scenarios—allowing the brave first responders to perform their jobs, save lives, protect property and then return home safely to their families. There is no finer calling...

x2nsat.com/

Garrett C. Hill is the CEO and founder of X2nSat, Inc. He guides the vision and cutting-edge culture of this forward-thinking satellite communications company with a mission to provide highly reliable wireless network and communication solutions to a variety of predominantly North American industries.

In his free time, he is a pilot and an active member of Rotary International. He believes in working hard and playing hard, and can be found debating the value of vertical integration of HTS architectures at various watering holes in Sonoma County, California.

SATCOM FRONTIER **PERSPECTIVES:**

BIG MOVES AHEAD FOR UAS ADOPTION AND FASTER INNOVATION AND ACQUISITION FOR SPECIAL FORCES

By SatCom Frontier Editors

Earlier this year there was an announcement that could usher in a new era for unmanned aircraft systems (UAS) in the United States.

The Northern Plains UAS Test Site in North Dakota became the first such facility authorized to conduct beyond-visual-line-of-sight (BVLOS) operations for UAS. By giving Northern Plains their stamp of approval, the Federal Aviation Administration (FAA) is helping to bring civilian agencies and commercial companies one step closer to greater UAS usage.

According to ***UAS Magazine***, "*The agency authorized the UAS test site to begin using ground-based sense-and-avoid technologies as it phases into BVLOS operations. The action outlines a path for unique testing and flight operations not widely available in the national airspace. The authorization allows for a large-platform UAS to take off from Grand Sky at the Grand Forks Air Force Base without the need for a manned chase aircraft.*"

Grand Sky is a UAS business and aviation park just outside Grand Forks, North Dakota, home of the University of North Dakota, a highly respected school for training pilots and for its unmanned aviation studies program.

Eliminating the need for a manned chase aircraft reduces the cost and operational overhead associated with UAS testing. That removes some of the hurdles that could otherwise slow the commercial use of UAS technology. As civilian agencies and commercial companies proceed with testing, Intelsat's satellites can provide the infrastructure needed for UAS communications.

The Intelsat Epic^{NG} high-throughput satellite (HTS) platform currently has two operational satellites: IS-33e and IS-29e. (The third EpicNG satellite, IS-32e, was recently successfully launched.)

Epic^{NG} is an open system that allows organizations to leverage the Ku-band antenna/modem infrastructure already in place on existing UAS. The IS-29e beam provides connectivity over all of North Dakota and has a perfect "look angle" for maximum efficiency. (There's more information regarding EpicNG at this direct link: ***intelsatgeneral.com/intelsat-epicng/***

Intelsat General has a proven history of reliably supporting UAS operations. The company has worked with a variety of agencies, including NASA, USAF and DHS, as well as platform manufacturers such as General Atomics and Northrup Grumman.

NASA, in particular, has an impressive track record of leveraging UAS. The agency began operating a Northrup Grumman Global Hawk in 2010 from NASA's Armstrong Flight Research Center to conduct earth-science missions. The Global Hawk's ability to operate in the upper stratosphere has contributed greatly to NASA's study of climate change.

Now, with the approval of the Northern Plains UAS Test Site, organizations such as NASA and Northrup Grumman have the ability to test and evaluate complex UAS operations that previously were not possible.

This approval also places North Dakota at the forefront of aviation and UAS research as this is the only site approved for BVLOS operations without a manned chase aircraft.

Finally, the FAA's approval is a testament to the state's dedication to emerging technologies, enabled in part by the innovative nature of the satellite communications industry.

UAS are uniquely capable of measuring, monitoring and observing remote locations of Earth in ways that are otherwise simply not practical. It will be exciting to see where these capabilities take commercial users and researchers with the availability of the Northern Plains UAS Test Site.

The preceding article is courtesy of Intelsat General's SatCom Frontier infosite and editorial team: ***intelsatgeneral.com/***

In recent years, expanding operations against Islamic militants have made the US military's Special Operations Command (SOCOM) increasingly important to ongoing national security.

To better support counter terrorism efforts, SOCOM commanders want to tear down any impediment to putting the best technology in the hands of the warfighter.

"*My goal is to simplify the process so anybody with an idea can help SOCOM,*" James F. Geurts, acquisition executive for US Special Operations Command, told *National Defense* magazine earlier this month. "*We see the acceleration of technology development and new inventions from our industry partners. My job is how to tie all those together, stay very close to the operational customers and closely tied to the inventors, engineers, entrepreneurs and folks with bright ideas.*"

One area of focus is being able to use lightweight unmanned aerial systems (UAS) that can be launched from the field without need of a runway. Because these UAS have small antennas requiring high-powered satellite signals, platforms such as Intelsat's Epic^{NG} spacecraft could provide the support needed for these SOCOM operations.

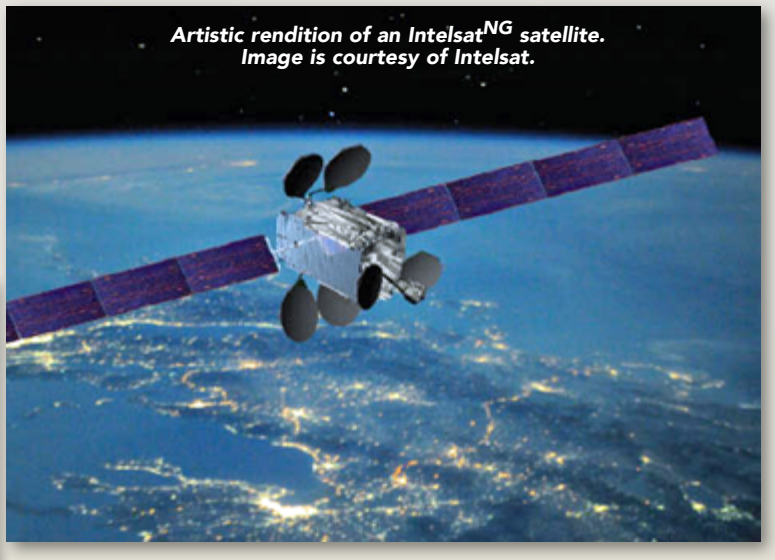
SOCOM has grown substantially over the past eight years. The number of active personnel has increased from roughly 56,000 in 2009 to 70,000 at the end of 2016, and the budget has jumped from $6 billion to $11 billion. Geurts, who manages a team of approximately 600 procurement officers, engineers and researchers, is quoted by National Defense as saying he "continues to see an exponential acceleration of requirements in almost every dimension."

Geurts has created an internal group called the office of "acquisition agility." This office is tasked with finding innovative technology that can solve an immediate SOCOM need, such as using the smaller UAS.

"*The commercial market drives miniaturization. I have systems that take runways and large crews to support. That can be a limiting factor,*" Geurts said in the article. "*I think you'll see us focusing on smaller, runway-independent, man-portable surveillance systems, with miniaturized sensors. So instead of a few expensive systems, we'll have more, affordable systems.*"

The new Intelsat Epic^{NG} satellite platform could play a role in this. Last year, Intelsat General demonstrated unprecedented performance in sending signals to and from a high-throughput Epic^{NG} satellite using a small, flat-panel antenna designed for aeronautical applications by Gilat Satellite Networks Ltd.

The tests were performed using Gilat's BlackRay 71 airborne terminal, with its mechanically steered 6 by 6 inch flat panel array. Data was sent from the small antenna to the recently launched Intelsat 29e satellite at a rate of 3.9 Mbps with an efficiency of 0.26 bits/Hz.



Artistic rendition of an Intelsat^{NG} satellite. Image is courtesy of Intelsat.

This compares to an uplink rate of about 1.8 Mbps and efficiency of 0.09 bits/Hz achieved with a conventional Ku-band widebeam satellite. This link was effectively two times the rate and almost three times more efficient than traditional widebeam satellites.

Combining this kind of portability with these new performance levels opens up a range of applications not just for SOCOM, but also for non-military applications, including search and rescue, infrastructure monitoring, forest fire suppression and agricultural monitoring.

The article also quotes retired Major General David Morris, an Army Special Forces veteran, as advising companies that wish to do business with SOCOM to enter into "cooperative research and development" agreements, so as to get an insider perspective on SOCOM needs. SatCom Frontier agrees and believes that this approach would better enable the US government to take advantage of existing commercial capabilities, test and evolve new technologies, and enable more rapid transition from prototypes to operational systems.

Due to the nature of their operations, the situational awareness needs of SOCOM have always been the highest of any service. It's not surprising that there is little tolerance for a Pentagon procurement system the National Defense article describes as "slow and cumbersome."

SOCOM—and the DOD in general—can tap into the agility and innovation occurring within the commercial space industry. SOCOM has been a leader in this area, working to bring industry into the acquisition process to access better technology faster. Geurts says this is done so "both sides can get a sense of walking in each other's shoes." It's helped SOCOM win six consecutive Pentagon awards for procurement excellence.

This type of collaboration with other military, intelligence, and civil space stakeholders will, hopefully, increase—because the technological innovation SOCOM needs today is the technology other service warfighters will need tomorrow.

The two preceding articles are courtesy of Intelsat General's ***SatCom Frontier*** *infosite and their editorial team.*

intelsatgeneral.com/

ROBUST SATELLITE TRACKING ON THE MOVE

By Dr. Rowan Gilmore, Chief Executive Officer, EM Solutions

With the launch of new high capacity, Low Earth Orbit (LEO) satellites that migrate across the sky, and the increasing importance of high speed communications from moving vehicles, ships, or planes, the need for accurate tracking between the satellite and its ground terminal remains as important as ever.

While most ground terminals track acceptably under benign conditions, tracking the satellite can still remain problematic at higher frequency bands (when the beam is more directional), at higher relative velocities or turbulence, or in obstructed environments. The true test of tracking ability comes in rough terrain, tight turns, or when passing near obstructions.

In this article, the use of 'monopulse' technology in mobile ground terminals to provide unsurpassed tracking performance is demonstrated.

SATELLITE TRACKING DESIGN APPROACHES

In frequency bands where high antenna gains are required and beams are directional, there are two broad approaches to acquiring and then tracking the satellite from the ground terminal.

The first, which is an open-loop approach, is to use the known position of the satellite in the sky to orient the antenna, and to reorient the antenna given the terminal's current heading. However, pointing accuracy to within a fraction of a degree is very difficult (and expensive) to achieve with an open-loop tracking system that relies solely on inertial measurement systems to steer the antenna. Furthermore, inertial measurement systems that rely on GPS measurements cannot account for signal refraction through the radome, and are therefore susceptible to radome variations and large offset errors that also depend on the angle of incidence.

GPS-assisted inertial units are also quite sensitive to multipath, so moving in the vicinity of buildings or trees could upset the INU (Inertial Navigation Unit), which would then result in pointing errors. To make matters worse, it would be very hard to know that these pointing errors had occurred, since such a system does not report on the actual pointing error.

The second, a closed-loop approach, is to track the satellite using its own transmissions. The terminal could, for instance, seek the orientation that maximizes the receiver signal, or satellite beacon signal, or some other derived signal, as in a "monopulse" system.

The signal maximum has a rather broad beamwidth, and finding its peak (at the center) requires mechanically scanning a conventional reflector antenna across the sky. Two examples of mechanical scanning systems are conical scan and step-track. These are deployed in so-called on-the-hop terminals,

which remain stationary in operation once deployed on location, but also in on-the-move terminals. However, a deliberate pointing-error must be introduced to verify the maximum has been reached, and this reduces the gain and effective power received; and can also respond too slowly for rapid vehicle motions. Furthermore, with mechanically scanned systems, fluctuations caused in the peak signal amplitude by signal modulation, obstructions or scintillation will also confuse the system and can result in loss of tracking altogether.

For all its on-the-move terminals, EM Solutions uses instead a variant of so-called 'monopulse' tracking, since it alone provides the most certainty and accuracy as to the true boresight direction. Monopulse systems are able to estimate the pointing error without any intentional scanning and without needing to deliberately mis-point the antenna.

Monopulse antenna systems are essential in large earth stations which have a very narrow beamwidth. Until quite recently, monopulse feeds have been too cumbersome and large to deploy in smaller terminals, since they require measuring a higher order mode pattern within the receiver feed.

One pattern, the fundamental mode (TE11 in circular waveguide), has the conventional antenna pattern for data communications, while higher order mode patterns (TM01, TE21, TM11 etc) have sharp nulls along the boresight. These modes can be used for more accurate pointing, since when the antenna is directly along boresight to the satellite, the power in the higher order modes in virtually nil. If the antenna moves off boresight, the level in the higher order modes increases rapidly. By continuously comparing the amplitude and phase change of a selected higher order mode with the fundamental mode, the antenna can be kept almost perfectly aligned. The deviations from boresight can also be calculated to give a continuous estimate of pointing error.

EM Solutions prefers to select the TE21 mode, as this can be used for both linear and circularly polarized signals, and the TE21 network can be designed to have quite a sharp null with high TE11 rejection, thus minimizing any deviations from boresight. It is important, of course, that the TE21 network has negligible effect on the fundamental TE11 signals in both transmit and receive. Otherwise this could compromise the antenna patterns, the G/T and the EIRP of the terminal.

ESTIMATING POINTING ERROR

When through its own motion the antenna feed deviates away from boresight and the sharp null of the TE21 mode is lost, the feed detects a non-zero amplitude and phase in the TE21 signal that is proportional to the amount and direction of the deviation. This pointing-error signal can be used in a control loop to steer the beam back to the correct orientation from its current position.

A monopulse system is able to report its measured pointing error to indicate the pointing accuracy achieved at any instant. Apart from being used to mute transmission when not accurately pointed to the satellite, measurement of pointing error also allows the availability of the system to be calculated.

A typical plot of pointing error during an off-road trial is given in Figure 1. Since the antenna uses a single parabolic reflector, both Rx and Tx beams are identically aligned. The pointing error is generally less than 0.1 degree over the full elevation coverage, indicating near-perfect continuity of communications even in the most demanding motion environment.

For this antenna, 0.1 degrees is about 6 percent of the 3dB beamwidth so the drop in magnitude of the transmit and receive levels is negligible. The motor power consumption is also shown, demonstrating that because of the mechanical balance achieved by the system, only a small component of the overall power budget is used for steering the antenna and maintaining lock. Power is required only to repoint the antenna, not to keep it actively scanning.

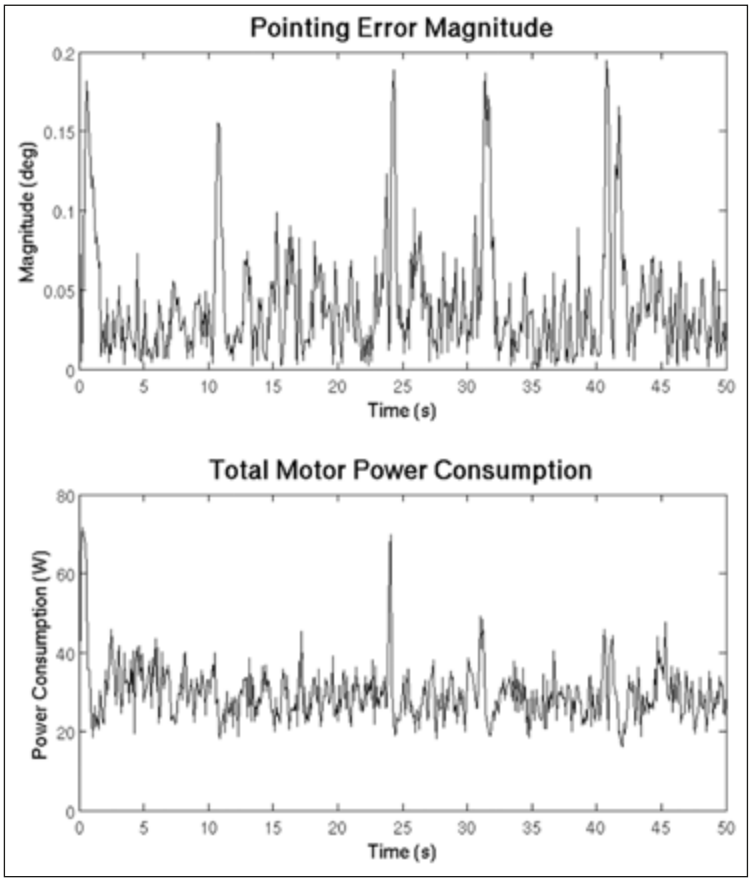


Figure 1. A real-time plot of the pointing error and motor power during a typical off-road trial for a Ka-band EM Solutions on-the-move satellite ground terminal.

A monopulse system requires a special antenna feed to generate the TE21 mode, as well as a second receiver chain to determine the pointing error from it. All antenna systems on EM Solutions' OTM terminals are designed with a number of properties that enable this. These include:

- *The diameter of the feed must be large enough to propagate both the fundamental and TE21 modes in the receive band, and the fundamental mode in the transmit band*
- *Sufficient narrowing of the feed to provide a good return loss for the TE21 mode*

- *Use of a ring-focused antenna and a suspended substrate network with probes around the feed in the radiation pattern 'dead zone' to extract the TE21 mode*

The TE21 signal can be extracted via coupling slots or probes. At Ka-band frequencies, waveguide slot coupled networks are small enough to be designed around the feed. At X band, a TE21 waveguide network would be prohibitively large for most mobile antennas, so a coaxial probe with planar circuit approach is used to make the TE21 network.

One approach to extract the TE21 mode is to add capacitively loaded probes about half way along the largest diameter section of the feed horn, where they couple effectively to the TE21 mode (*see Figure 2*). For the best results, the use of 8 probes gives full network symmetry and allows the system to use either RHCP, LHCP, or LP.

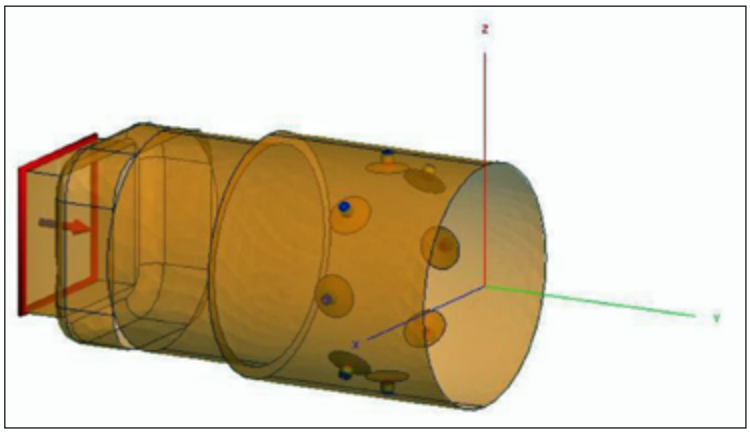


Figure 2: An X-band feed horn showing probes around the diameter of the horn to sample the amplitude and phase of the TE21 signal generated within the feed.

It is important that the presence of the probes does not affect the data transmit and receive pattern of the antenna in the fundamental (TE11) mode used for the main data signal. For the X-band example in *Figure 2*, numerical modeling at 8 GHz showed that the patterns with and without the probes are almost indistinguishable, as shown in *Figure 3*. This is as expected, since the azimuthal periodicity of the probes and their connections, together with the modal cut-off frequencies of the relevant feed section, prevent the generation of new modes which could alter the designed pattern of the feed.

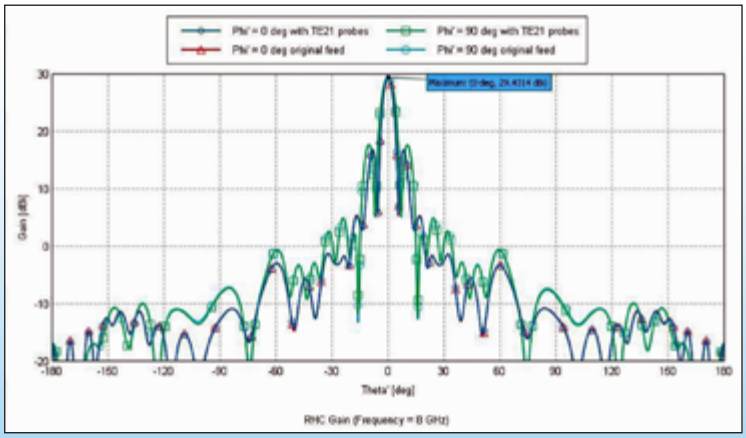


Figure 3. A plot of the radiation patterns of an X-band antenna feed with and without the TE21 probes, according to numerical modeling at 8GHz (Right Hand Circular polarization)

At the outputs of the TE21 probes, EM Solutions uses planar circuits in waveguide to generate the sum and difference signals from various combinations of the probes, and routes these behind the antenna to the antenna control unit for processing. The waveguide network wraps around the feed itself, and takes advantage of the dead zone under the antenna subreflector to avoid impacting the fundamental antenna pattern. *Figure 4* shows an X-band monopulse feed.

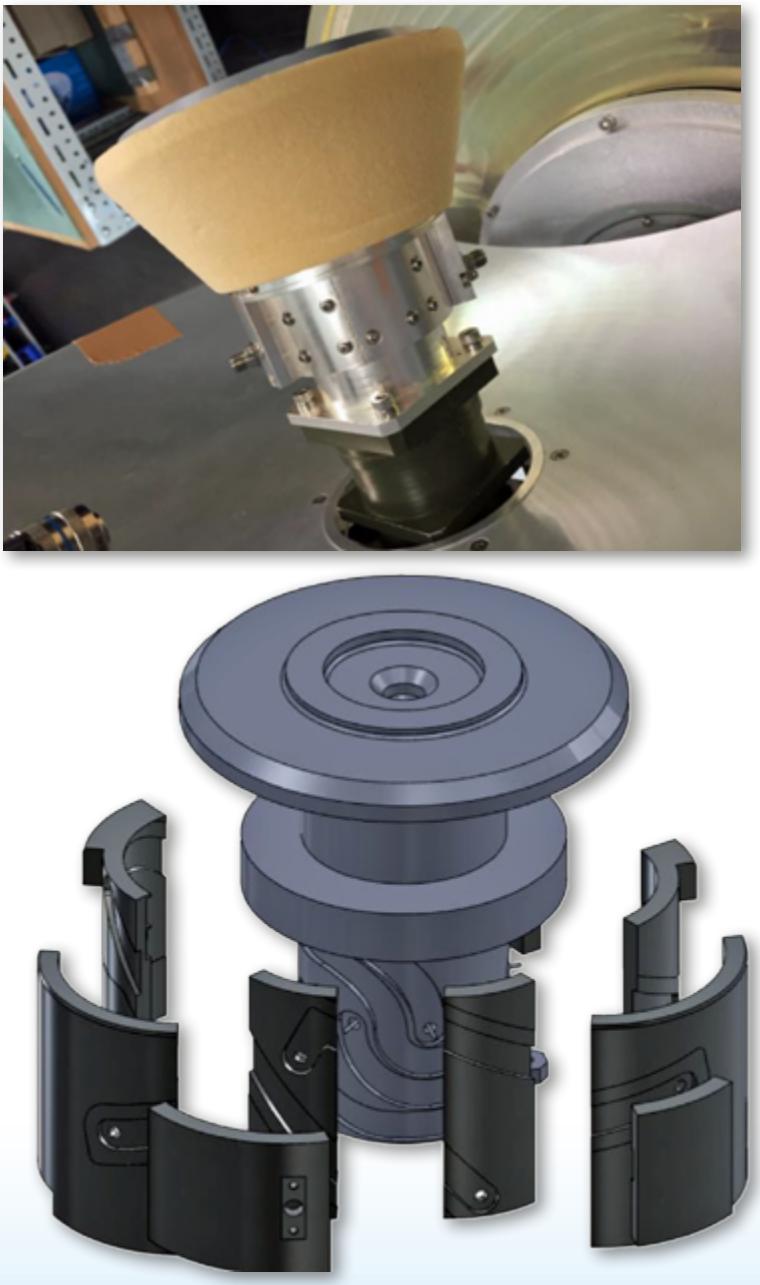


Figure 4. Photograph (upper) of an X-band antenna feed horn, and schematic (lower) of the waveguide-based network used to generate the required monopulse signals from the TE21 probes and route them to the receiver and antenna control unit for processing.

TRACKING TEST SEQUENCES PROVE SUPERIOR PERFORMANCE

EM Solutions COTM terminals automatically output approximately 50 variables detailing performance during operation. These are recorded 128 times per second, and include the measured pointing error and signal strengths.

Some of the more useful plots that can be obtained from the data in addition to the pointing error are the C/No level of the received signal and the azimuth and elevation position of the antenna system itself.

Figure 5 shows some of the important points in the plots. The top curve, of the signal C/No, shows steady tracking of the satellite except for a momentary drop in C/No caused by an obstruction. The bottom curve, of the reported pointing error, shows a steady state error close to zero, but that momentarily increases to 0.4 degrees during the obstruction.

After the signal is reacquired, the pointing error briefly peaks until the satellite is reacquired. During this time, the block up converter (BUC) would be muted to avoid false transmission, but tracking would be predicted and still continue, based on input from the terminal INU and gyroscopes to compensate for motion until the satellite was reacquired. This 'gyro-hold' mode minimizes reacquisition time since the terminal is already pointing close to the satellites predicted position.

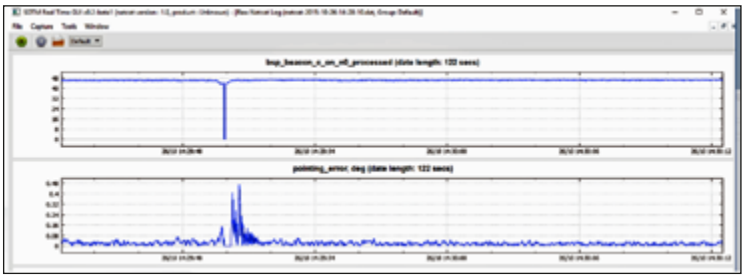


Figure 5. Example of real-time recorded data output. The top plot shows the received C/No level of the fundamental signal, and the bottom plot the pointing error at the same time

In the example test sequences shown below, EM Solutions has included Google Earth plots showing the track taken by the vehicle recorded by the on board GPS. Obstructions are noted in red, and clear 'line of sight' is noted in green. Obstructions observed by the tracking system can then be checked against trees or buildings on the Google Earth image.

TEST SEQUENCES

A — NO MOTION

The simplest test is when the vehicle is not in motion and stationary.

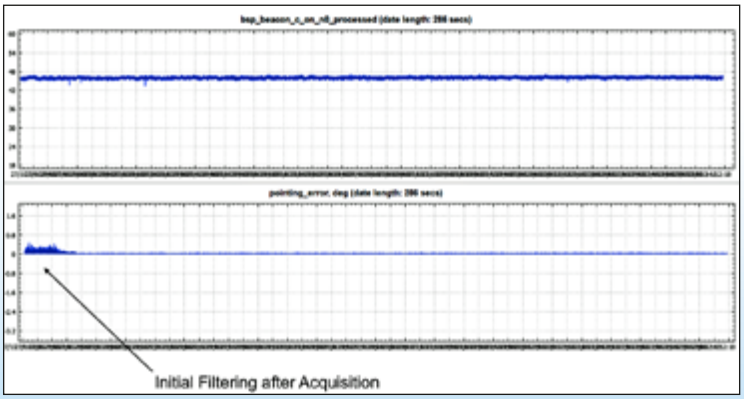


Figure 6. No Motion

Figure 7. Google Earth Track No Motion
As expected, the signal level is constant and the pointing error is zero, indicating continuous and steady operation.

B — DRIVING TO THE TEST AREA

This example shows the vehicle being driven along sealed roads to a test area, encountering occasional obstruction from trees (shown in red on the Google Earth plot). The C/No drops to zero during those obstructions, the terminal switches to its gyro-track mode, and the pointing error is generally less than 0.2 degrees.

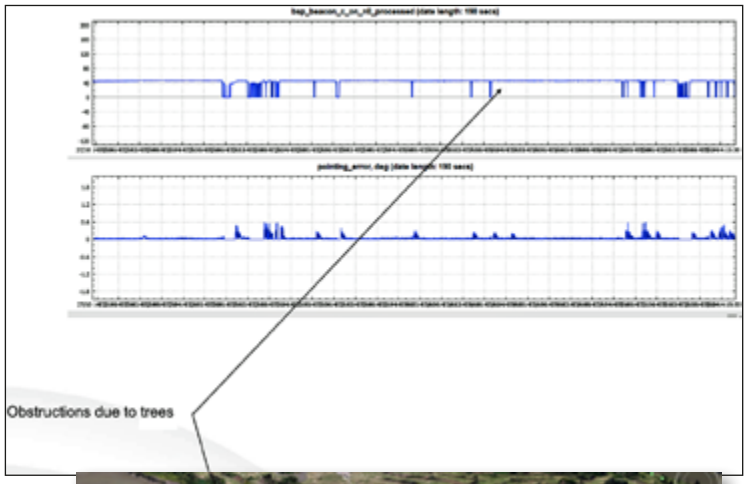


Figure 8 (top). Sealed Road Driving

Figure 9 (bottom). Google Earth Track Sealed Road

C — CONTINUOUS TURNS

When the vehicle is driven in a series of clockwise turns, the azimuth recorder shows a continuously increasing angle. The C/No remains strong, fluctuating a fraction of one dB, and the pointing error remains less than 0.1 degrees. The system remains continuously locked onto the satellite.

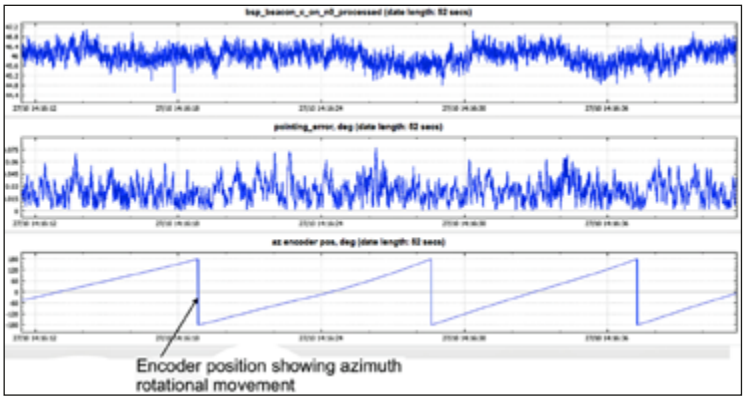


Figure 10. Clockwise Turns. The bottom plot shows the azimuth angle (heading).

Figure 11. Google Earth Track Clockwise Turns

D — FIGURE OF EIGHT TURNS

This is a test that many terminals fail. When the vehicle is driven in a series of figure of eight turns, the azimuth recorder shows an angle that varies between +180 and -180 degrees. The C/No remains strong, fluctuating a fraction of a dB, and the pointing error remains less than 0.1 degree.

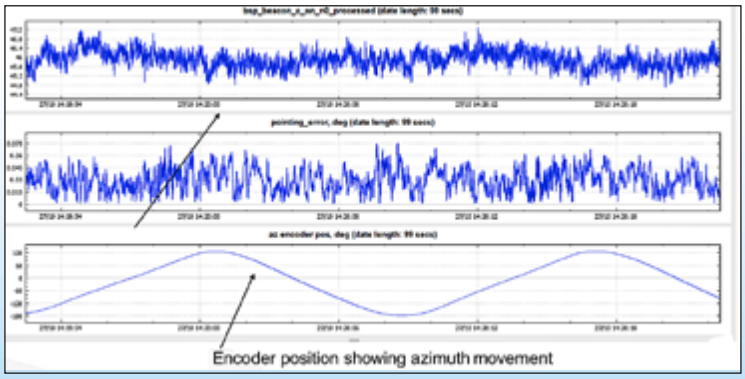


Figure 12. Figure 8 Turns

Figure 13. Google Earth Track Figure 8 Turns

E — SPEED BUMPS AND OBSTRUCTIONS, URBAN ENVIRONMENT

This test shows the impact of speed bumps and obstructions due to buildings. For certain obstructions, the pointing error is represented by a value of -1deg during the obstruction (as shown below). This value is used by the internal firmware only to indicate signal loss. The terminal is not affected at all by the speed bumps (the elevation encoder records the angular jerks but the pointing error remains constant), and the terminal instantly reacquires once the satellite comes back into view.

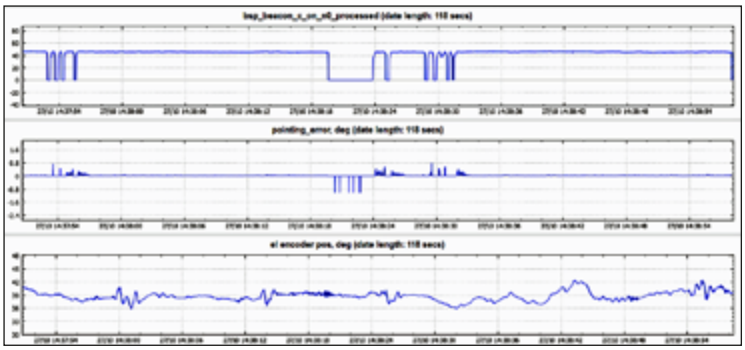


Figure 14. Data over Bumps and Urban Obstruction. The bottom plot shows the angle (in the sky) recorded by the elevation encoder.

Figure 15. Google Earth Track - Speed Bumps and Building Obstruction

F — UNDERPASS (10 SECONDS)

This test shows the impact of longer obstructions, in this instance generated by an underpass of approximately 10 seconds. The terminal reacquired the satellite immediately after emerging, remaining pointed at the predicted satellite position during the obstruction because of its gyro hold mode.

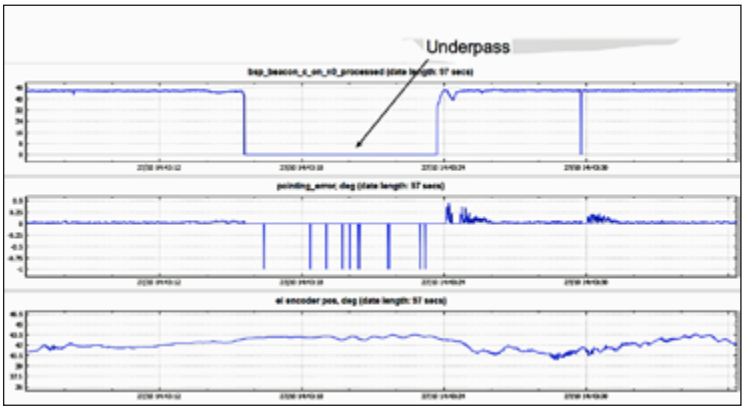


Figure 16. Underpass

Figure 17. Google Earth Track Underpass

G — HIGH SPEED DRIVE WITH RAPID ACCELERATION AND HARD BRAKE

This test was a high speed drive along sealed road with sudden acceleration and then braking applied. The pointing error remained less than 0.1 degrees to throughout.

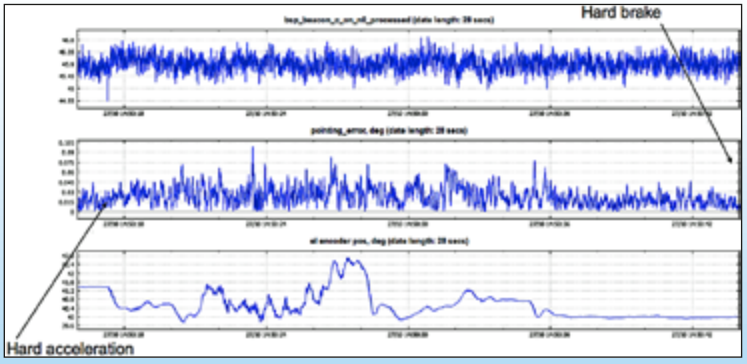


Figure 18. Rapid Acceleration + Hard Brake

Figure 19. Google Earth Track Rapid Acceleration + Hard Brake

VH — HIGH SPEED, OFF-ROAD ('CHURCHILL' TERRAIN)

The most severe test on land is off-road. *Figure 20* shows an example of both the elevation and cross elevation axis tracking error and associated histogram plots, while *Figure 21* shows an example of the tracking error and carrier to noise plot.

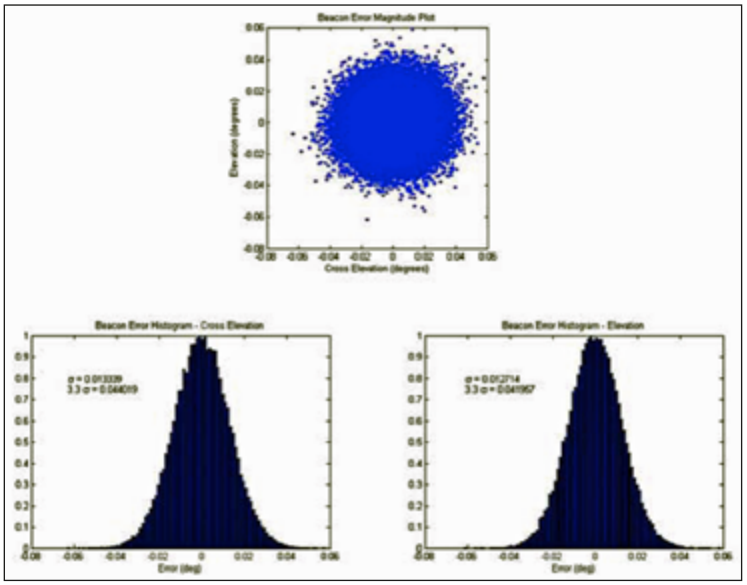


Figure 20. Off-road Elevation and Cross Elevation Tracking Error and Histogram Plots for an EM Solutions 3-axis OTM terminal (a) Beacon Tracking Error Magnitude in the Elevation and Cross Elevation Axis (degrees) (b) Cross Elevation Beacon Tracking Error Histogram (c) Elevation Beacon Tracking Error Histogram

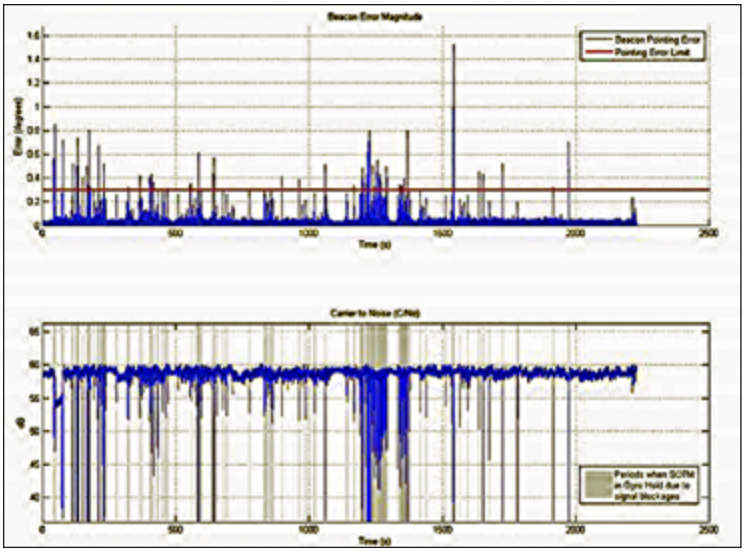


Figure 21: Magnitude of Pointing Error (top) and Carrier to Noise Plots (bottom) Recorded over Rugged Off-Road Terrain. The pointing error only exceeds specification of 0.3 degrees when the signal is lost due to blockages, as indicated on the C/No plot. The time scale now extends over nearly one hour.

Figure 22. Example Google Earth Image of Vehicle Path and Tracking Performance Off-Road

CONCLUSION

The use of a monopulse tracking system on small on-the-move satellite ground terminals is not cost free. The monopulse technology requires a more complex antenna feed system to generate a second antenna pattern that can be used for steering (the TE21 mode), and a second receiver chain to generate from this a pointing error control vector that can be used within an antenna control unit to steer the antenna.

However, field tests and customer reports have proven that such a system is far more reliable and robust at acquisition, tracking, and reacquisition of the satellite than other systems. The ability of a monopulse tracking system to report its own pointing error indisputably proves that tracking performance is accurate to within millidegrees as long as the satellite is not blocked.

For clients requiring maximum link availability and up-time, and more assured communications, the additional capital cost of a monopulse-steered ground terminal is negligible compared to the additional bandwidth costs and interruptions to service caused by inferior mechanically scanned systems. A single monopulse controlled system can be used to compensate for motions induced in any operating environment, whether on land, sea, or air.

emsolutions.com.au/

Rowan Gilmore joined EM Solutions as a Director in 2007 and became Managing Director and CEO in October 2011. His role is to lead EM Solutions to achieve its vision to become recognized internationally as the leading designers and manufacturers of the most innovative and highest quality microwave product technology.

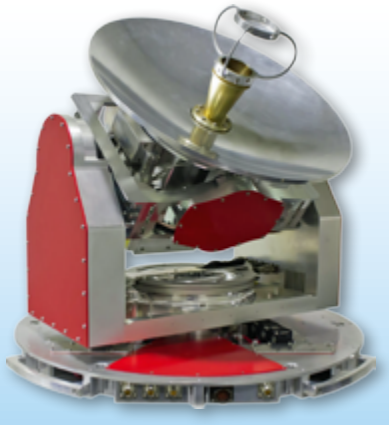
Rowan will be known to those in the microwave engineering community who have attended his short courses on microwave circuit design and RF wireless systems offered by Besser Associates and CEI Europe since 1990.

His previous experience includes Vice President, Engineering at Compact Software, where he introduced the world's first harmonic balance nonlinear circuit simulator, and as Vice President, Network Services Europe for SITA-Equant, the global airline IT company, now part of France Telecom's Orange network. Most recently he was CEO of the Australian Institute for Commercialisation, where he helped numerous start-up companies and worked to accelerate technology transfer between research institutions and industry.

Rowan obtained his D.Sc. in Electrical Engineering from Washington University in St Louis. He is an adjunct professor of both Business and Electrical Engineering at the University of Queensland, and was elected a Fellow of the Academy of Technological Scientists and Engineers in 2009.

Author's note
EM Solutions wishes to acknowledge the valuable support and collaboration of ***Indra Sistemas SA*** *of Spain in the development and testing of the X-band terminal described in this article.*

EM Solutions' Cobra 1M Ka-band COTM Terminal.



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THE HPA CORNER:
THE FUTURE OF HOSTED PAYLOAD POLICIES

by Bryan Benedict, Senior Director, Innovation & Satellite Programs, SES GS

As we move forward into 2017, the space industry remains hopeful that the new US Administration will allocate the necessary funds to execute space programs critical to national security.

For a number of years, commercially hosted payloads were touted as one of the best ways to provide some of these capabilities in a severely restricted budgetary environment.

The Hosted Payload Alliance's mission was to provide awareness regarding this affordable solution to a range of US government stakeholders in hopes that the US government would embrace hosted payloads as a viable alternative to major programs of record—or at least as a way to test new technologies before they were deployed in multi-hundred-million-dollar programs.

The Hosted Payload Office was established at the USAF's SMC (Space and Missile Systems Center) to address some of the contracting challenges related to commercially hosting US government payloads, and IDIQ contracts were awarded to a number of companies.

It appeared that US government-commercial collaboration was on the horizon. It was extremely encouraging when it appeared the US government was seriously considering use of hosted payloads—they included hosted payloads in *Analyses of Alternatives*, issued RFIs and held Industry Days.

At the same time, however, it seemed that there was a sense within the Department of Defense (DoD) that the budget challenges were temporary—if they would hunker down and ride through the storm, restoration of big budgets for big programs of record was just around the corner.

Unfortunately, with around 19 trillion dollars of debt, it may be that the era of big space budgets is gone forever and that collaboration with industry is the only path available.

This column's question for HPA Members is…
Do you believe that the financial policies of the Trump administration will provide an environment more or less conducive for hosting US government payloads on commercial satellites?

"We expect that the emerging financial policies of the new administration support the governmental use of commercial industry, and are consistent with national space policy and the hosted payload model, which aims to provide shorter schedules, reduced costs, greater access to space, and operational flexibility.

"As public-private partnerships gain traction in the space sector, we anticipate that the new administration will encourage the government to work with industry to explore more affordable ways to upgrade space assets and manage the development of new space infrastructure.

"With current policies focused on advancing industry's capabilities and role in competitively serving US government needs, hosted payloads offer proven solutions for a cost-constrained, commercially supported, resilient architecture for space-based missions.

*"Industry can also enhance hosted payload solutions with offerings like data services and communications services for a variety of missions, incorporate Government Furnished Equipment (GFE) as hosted payloads on a commercial satellite, and integrate capabilities consistent with the new administration's increased focus on national security."—**Al Tadros***, Civil & DoD Business, **SSL**

hostedpayloadalliance.org/

Established in 2011, The Hosted Payload Alliance (HPA) is a satellite industry alliance whose purpose is to increase awareness of the benefits of hosted government payloads on commercial satellites. The HPA seeks to bring together government and industry in an open dialogue to identify and promote the benefits of hosted payloads. The HPA:

- *Serves as a bridge between government and private industry to foster open communication between potential users and providers of hosted payload capabilities*
- *Builds awareness of the benefits to be realized from hosted payloads on commercial satellites*
- *Provides a forum for discussions, ranging from policy to specific missions, related to acquisition and operation of hosted payloads*
- *Acts as a source of subject-matter expertise to educate stakeholders in industry and government.*

SatFinder

Satellite Database & Calculation Software

DATABASE

Information on over 500 satellites (orbital location, frequencies, EIRP, G/T, SFD, bandwidth, programming etc.)

Information on 9,000 companies (address, tel, fax, web, products, services and contact names etc.)

Information on 19,000 executives in the commercial satellite industry.

800 hundred EIRP, G/T & SFD maps in color not published anywhere else.

CALCULATION

Has full up-down digital link budget calculators with input provision for uplink power control (UPC), ALC, various interferences and multiple carriers.

Finds HPA size, uplink power requirements, bandwidth and power usage per carrier.

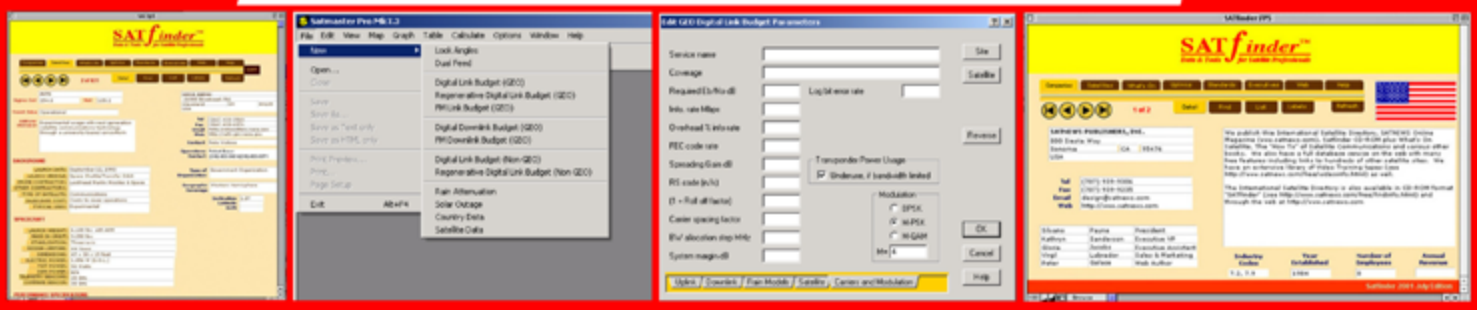
Calculates atmospheric losses and rain fade margins for any desired availability on uplink and downlink.

Handles BPSK, QPSK, M-PSK or M-QAM with any FEC code rate.

Determines power or bandwidth limited modes and calculates the power equivalent bandwidth, if appropriate.

Provision for RS codes or 'Turbo' modems. Option for rain up AND rain down scenarios where uplink and downlink are from/to the same city.

UPDATED QUARTERLY!



http://www.satnews.com/satfinder

LOW PASSIVE INTERMODULATION DISTORTION IN SATCOM

By Ian Timmins, Ph.D., Principal RF Enginer, AvL Technologies

X-band satellite communication is widely used by the US and other militaries because this portion of the RF spectrum provides overall performance advantages that other bands do not, including:

- *Minimal rain disruption (rain fade)*
- *Resilience to interference*
- *Delivery of data rates approaching that of other less resilient RF spectra*
- *Ability to operate with relatively small, remote SATCOM terminals*
- *Acceptance by most developed nations as a spectrum that is reserved for governmental use*

However, communicating in X-band frequencies can be technically challenging, as well. X-band transmit signals require active filtering, and receive signals are vulnerable to unintended passive intermodulation (PIM) products, which cause signal degradation and distortion.

The frequency ranges for X-band, as designated by the International Telecommunication Union (ITU), are 7.25 GHz to 7.75 GHz for space to Earth communications (receive) and 7.9 GHz to 8.4 GHz for Earth to space communications (transmit).

This unusually narrow separation between receive and transmit sub-bands makes X-band inherently vulnerable to the generation of unintended intermodulation products (IMPs) that can lead to interference and disruption.

There are two types of IMPs: active and passive. Active IMPs are generated through an active component, such as the transmit amplifier. The problematic IMPs can be filtered and rejected within the amplifier using established filter design techniques. Passive IMPs (PIMs) are typically the most troublesome, as discussed in detail below.

Satellite communication antennas operate with simultaneous transmit and receive signals traveling through RF "pathways" in critical, passive components that are shared, such as the feed horn, polarizer and diplexer.

PIM occurs in X-band systems when two or more high power tones generated by active components (amplifiers) in the transmit band mix at device "nonlinearities" such as standard waveguide flanges or other surfaces where microscopic discontinuities or corrosion may naturally occur. The higher the transmit signal amplitudes, the more pronounced the effect of the nonlinearities and the more prominent the undesirable consequences in the receive band.

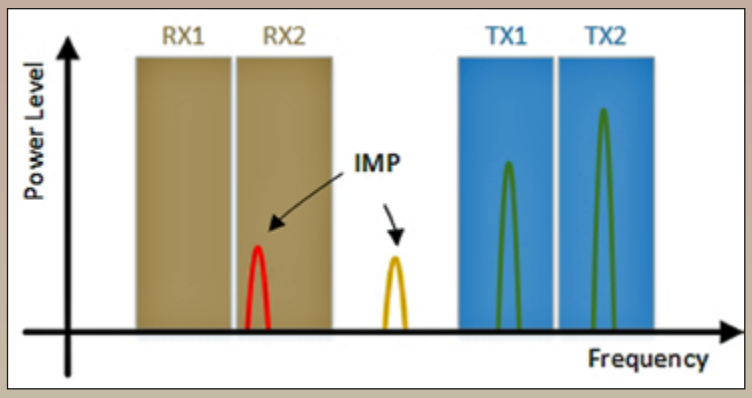
PIM Generation

The foundation of PIM effects is the use of two distinct frequencies in the antenna, whereby a non-linear passive component is excited by both frequencies simultaneously. When the intermodulation interference products are generated by the nonlinear materials in the passive components, they appear as the sum, or the difference, of the two original signal frequencies. They also may add in a manner where either, or both, of the original frequencies are multiplied by an integer as well. Typically, however, as the order of these integers increases, the amplitude of the product decreases.

Nonetheless, as the number of channels increases, the number of possible intermodulation products increases very rapidly, ultimately making systems with an increased number of channels more susceptible to passive intermodulation.

Material selection for PIM mitigation is critical. Metals to avoid on antenna components include ferromagnetic metals such as ferrites, nickels and steels, including some types of stainless steel. These materials exhibit hysteresis when exposed electromagnetic phenomenon, resulting in PIM products. Metals that oxidize quickly or produce significant amounts of rust also should be avoided.

PIM detection and measurement can be challenging. PIM products are typically low level compared to signals intended for data transmission. But, due to the fact that transmitters share many of the same transmission lines as the receiver (as parts of the antenna and feed system), even low level PIM products can cause significant problems.



PIM and Low PIM in Action

One common application for X-band communications by the US military is communicating with drones. Data, imagery and streaming video collected by unmanned systems can be relayed to soldiers in remote locations who receive it with X-band antenna systems. If the antenna system is experiencing PIM, the receive signal can be degraded to the point that the feedback loop fails and communications are lost, or the data being received is so degraded it's unreadable.

RF systems installed on mobile platforms intended for use during transit are of particular vulnerability to the effects of PIM. It has been shown that mechanical vibration and motion directly impact the levels of intermodulation products produced at metal-to-metal junctions.

Unmanned aerial systems, for example, are airborne platforms whereby operations depend on the integrity of the RF communications links for command and control. For an airborne platform, mechanical strain due to motion and vibrations are pronounced in comparison to more inert fixed environments.

In this case, the effects of PIM causing a communications outage could not only result in the loss of the vehicle, but threaten the safety of persons located on the ground. For marine environments, the constant motion of the vessel due to rolling seas may play a more significant role than the vibrations experienced on an airborne platform, but nonetheless create an environment whereby the impact of PIM needs to be considered more substantially.

PIM is a reality of RF systems that directly threatens operational readiness for military communications as soldiers rely heavily on a constant flow of information. Though this effect can be subtle, soldiers in theater are often in harsh environments—hot and sandy or damp and salty—that can create or hasten PIM-inducing issues on an antenna. As such, many US military communications programs specify that antennas must be designed and produced as "Low PIM" in an attempt to mitigate the issue altogether.

Satellite and marine systems also are inherently more susceptible to PIM effects. This is due in part to the fact that high power transmitters and low-noise receivers are used in the same system. When the intermodulation products generated from the high power signal become significant in amplitude and when they fall into the receive band of the system, the communications link is jeopardized.

Marine systems have the added challenge of corrosion susceptibility, resulting in the potential for PIM generation well after the systems are initially tested and deployed.

Low PIM Antenna Design

An antenna designed to be Low PIM, simply stated, is a well-engineered antenna made with high-quality components whereby special consideration is given to PIM. At AvL Technologies, a Low PIM antenna is designed with a holistic approach, such that every component and subsequent metal-on-metal junction in the signal path is considered.

Design is not simply done as individually cascaded components in the signal path. Considering the interface of these components as a collective is a critical step to ensuring the system is resilient to PIM—not only at the time the system is delivered to the customer, but as the system ages it is not prone to developing effects that would induce PIM. Thus every metal-to-metal interface in the system is considered.

The waveguide components for example, are made of high-quality materials that are explicitly made to be the same materials in the feed to avoid a metal on metal junction that would induce oxidation. This is the same for the OMT and the polarizer components.

Cables and connectors are an extremely common source for causing PIM. AvL selects these materials carefully and incorporates them into each antenna design in a way that minimizes susceptibility to motion. AvL antenna designs also ensure that the connectors are solidly mated and environmentally sound to keep moisture from causing rust and keeping debris out.

During the manufacturing process for cable assemblies, AvL uses cable and connector termination processes that help reduce oxidation. These processes over time, due to the flow of RF signals through the cable and connector transitions, are intended to protect the system from developing oxidization and resulting in increased susceptibility to PIM.

This holistic approach to designing and manufacturing antennas is a trademark of AvL products. All AvL antennas are designed to be extraordinarily sturdy, efficient and reliable. Antennas produced for military applications are designed to be operated in extreme conditions and many are MIL 810 compliant or qualified—in addition to being designed for Low PIM.

avltech.com/

Ian Timmins, Ph.D., is the Principal RF Engineer at AvL Technologies. Prior to joining AvL, Ian was VP of Engineering for Optical Cable Corporation's Enterprise and Harsh Environment lines of business. He previously held technical roles with Dell Computer Corporation, Cisco Systems and COM DEV Space Group. Ian holds a Ph.D. in Electrical Engineering and is an adjunct professor with Western Carolina University.

MODERNIZING MILSATCOM INFRASTRUCURE FOR COMMS-ON-THE-MOVE (COTM)

Late last year, C4ISR sponsored a webinar with LTC Joel Babbitt, the Product Lead in the Wideband Enterprise Satellite Systems (PL WESS) office of the United States Army.

The webinar covered the Army's satellite modernization efforts, the challenges the Army currently faces due to aging infrastructure and the trends driving the need for increased satellite bandwidth. One of the topics that LTC Babbitt discussed in depth was a shift towards "Comms-On-The-Move," and the need to upgrade satellite infrastructure to make this shift possible.

To learn more about "Comms-On-The-Move," the disadvantages of older satellite ground systems and the reasons why the military is increasingly turning to MILSATCOM to empower these next-generation solutions, we spoke to Tonney Chandler, the program manager for commercial SATCOM at SES Government Solutions. Tonney is well versed in the military's use of satellite, having previously served as the Chief, Tactical Communications Branch, Architecture, Operations, Networks and Space in the Office of the Chief Information Officer of the Army. The following conversation presents what Tonney had to say:

GOVSAT REPORT

What specific use cases is the Army looking to utilize satellite for in theater operations? What capabilities and benefits are they looking to deliver to warfighters over satellite?

TONNEY CHANDLER

First, I can only speak for what we are witnessing on the commercial side as I cannot fully address what LTC Babbitt is witnessing within the Army and Department of Defense.

We are still seeing requirements for basic communications. However, that requirement is shifting and evolving from "Comms-On-The-Halt" to what we refer to as "Comms-On-The-Move." This means that they're looking to be able to utilize communications as they move through the battlefield—much like how you would use your cellphone. This way they would be constantly connected—not losing data and not losing or missing any information. And, of course, on the battlefield, intelligence is very important. That is still — and will always be—a major requirement for the military. But now the focus is being able to get what you need it, when you need it.

Communications is evolving as well. Across the federal government, we're seeing that basic communications don't just include voice anymore. There is an expectation to have access to real time video teleconferencing (VTC) and other communications and messaging functionalities.
These are all capabilities that the military could look to embrace in theater, and that requires significant bandwidth. Video continues to grow in importance when it comes to intel.

Today, you have eyes in the air, thanks to Remote Piloted Aircraft (RPAs) that generate video that has to be transported back to the intelligence analysis personnel that analyze it and determine what needs to be done based on

what they're seeing. Video—especially high quality video—is essential for intelligence today, and it requires a lot of bandwidth. This HD data helps soldiers in many ways, including helping them identify targets with higher accuracy. There is also a large demand for satellite bandwidth for RPA training in CONUS.

GOVSAT REPORT

During the webinar, LTC Babbitt discussed challenges the Army is facing with archaic and antiquated terminals and satellite infrastructure. What specific problems does this antiquated infrastructure pose to the Army? What new technologies and capabilities are they unable to utilize as a result of this aging satellite infrastructure?

TONNEY CHANDLER

The older technology tends to be less efficient with bandwidth usage. With the newer technology, you can get higher throughput with less power. The older antennas have less gain and require more power, so you're essentially trading power for gain of information. You can only go so high with power, and that limits your ability to pass high amounts of information. With newer, more efficient antennas and receivers, you can get better throughput. This makes the connection faster and more powerful without expending more power.

Then there's the issue of size and weight. As the military is looking to move towards "Comms-On-The-Move," which means these systems need to be more transportable. One of the barriers to "Comms-On-The-Move" has historically been the size of the satellite equipment and terminals. They wouldn't fit into Humvees, and they certainly wouldn't fit onto RPAs—they were too big and heavy. They've made significant advancements in this area. These newer technologies don't require as much of a trade-off between size and power. They deliver throughputs on par with older systems, but are much smaller, lighter, and more flexible.

GOVSAT REPORT

LTC Babbitt mentioned cost savings as a reason for using WGS satellites for military communications instead of COMSATCOM. If it's less expensive, for what reasons would the Army want to utilize COMSATCOM?

TONNEY CHANDLER

There are only so many WGS satellites. There are eight launched right now, and I believe ten to twelve planned in total. There are limits to the amount of bandwidth that is available aboard those satellites. This means that operations in areas with over-taxed and over-utilized WGS satellites could also create a need for COMSATCOM bandwidth.

The satellite industry produces satellites faster than the government. They have faster refresh cycles and constantly launch new satellites into orbit that take advantage of the latest technologies. Aside from providing bandwidth where WGS may be unable to provide it, using COMSATCOM services gives the military access to advanced satellite technologies that could take them years to fund, develop and launch.

There are also multiple vendors with a wide portfolio of satellites. All told, there are numerous COMSATCOM satellites in orbit that are capable of providing bandwidth to the military. If one vendor's satellite does not have the bandwidth, or doesn't have coverage where necessary, another vendor will. By working out relationships with the satellite industry, the military will always have satellite bandwidth and capacity when and where it needs it.

GOVSAT REPORT

Are there less costly options (inclined satellites, hosted payloads) that could make COMSATCOM services available at lower costs to the Army? How could these options be utilized by the Army? Why aren't they being utilized more now?

TONNEY CHANDLER

Inclined satellites are certainly something that the Army can utilize to save money, since those satellites are older, in lower demand and—as a result—are less expensive. The reason these satellites are often considered less desirable is due to the fact that they move, and need to be followed with tracking antennas. But that's fine for today's "comms on the move" users, because their antennas are tracking antennas capable of tracking the satellite.

Why aren't inclined satellites being used more? I'd say that there is a perception issue. There is a stigma and some perceived risks regarding the viability and length of life of the satellite. The military may feel that the health and welfare of the satellite may not be conducive to the length of operations for the mission. Another reason why inclined satellites may not be used more frequently is availability. Because it is the business model of Commercial satellite providers to operate satellites that are station-kept (little to no movement for stationary users), they tend not to keep inclined satellites in the inventory. As a result, there are only so many inclined satellites in orbit and they may not be where capacity is needed.

Hosted payloads are also an option for the military if they're looking to save money. Hosted payloads would be an alternative to launching a purpose-built satellite for an application. Instead, that payload could be launched on an industry partner's satellite for a fraction of the cost. However, regarding hosted payloads, there is understandable apprehension because the government would be putting its requirements on a commercial vendor's satellite with limited control on the overall operation of that satellite. The advantage is that the requirements and capabilities are integrated by the vendor on an already existing platform specially tailored at a lower price. The trade-off is less control of the commercial asset.

To learn more about cost-saving inclined satellites, download the whitepaper, "***How Inclined Capacity Reduces Costs For The U.S. Government*** at

ses-gs.com/govsat/resources/white-paper-2-2/govsat/

These articles are republished, courtesy of The Government Satellite Report (GSR) and Executive Editor ***Ryan Schradin****. He is a communications expert and journalist with more than a decade of experience and has edited and contributed to multiple, popular, online trade publications that are focused on government technology, satellite, unified communications and network infrastructure. His work includes editing and writing for the GovSat Report, The Modern Network, Public Sector View, and Cloud Sprawl.*

His work for the Government Satellite Report includes editing content, establishing editorial direction, contributing articles about satellite news and trends, and conducting written and podcast interviews. Ryan also contributes to the publication's industry events and conference coverage, providing in-depth reporting from leading satellite shows.

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TRANSFORMING SATCOM REQUIRES "ANYTIME/ANYWHERE" ACCESS AND CAPABILITIES FOR GOVERNMENT USERS

By Rebecca M. Cowen-Hirsch, Senior Vice President for Government Strategy and Policy, Inmarsat

In the modern era of global conflicts and catastrophes, events emerge swiftly and unpredictably, which means government/military users providing support must stand ready to deploy "anytime/anywhere."

In doing so, they rely upon satellite communications (SATCOM) that goes where they go—as fast as they can get there. Department of Defense (DoD) users need instant access to resilient, robust and secure SATCOM around the globe, for the full spectrum of engagement.

Commercial SATCOM (COMSATCOM) companies help military users achieve these objectives. They are constantly coming up with new innovations to extensively expand capabilities. They build systems from the ground up with U.S. government customers in mind, thereby, augmenting satellite resources cost-effectively, wherever and whenever needed.

The private sector understands the military's architecture requirements, budget restrictions and cultural challenges. They know how to seamlessly integrate with military satellite communications (MILSATCOM) to provide even higher throughput and performance for optimal redundancy, diversity, protection, scalability and global portability—the ultimate resilient, interoperable approach.

Indeed, thanks to COMSATCOM, advancements from the private sector can be integrated into the baseline of DoD architectures to "ease the pain" of agencies that must meet the users' needs under the ongoing challenges of overstretched budgets. Expanding the presence of such integration would enhance industry's relationship with government, elevating it to that of a fully realized partnership. This partnership would support seamlessly augmented connectivity and functionality, allowing users to operate reliably anywhere the mission takes them.

However, the DoD budget challenges are combining with a piecemeal and antiquated SATCOM procurement models, as well as cultural challenges that prevent this, especially when it comes to augmenting government systems with the very best that industry has to offer.

The government still primarily pays for COMSATCOM through Overseas Contingency Operations (OCO) funding—regardless of private industry's proven track record in supporting mission-critical operations such as Airborne Intelligence, Surveillance and Reconnaissance (AISR), Very Important Persons Special Airlift Missions (VIPSAM), Blue Force Tracking (BFT) and emergency response and public safety.

To further complicate acquisitions, key roles are assigned in a fragmented pattern within the Joint Staff, US Strategic Command (USSTRATCOM) and other government entities. Subsequently, agencies acquire terminals through military services and embed them into programs of record with no direct correlation to space system timelines. These programs of record have frequently suffered from delays and/or budget overruns, which occasionally qualify as Nunn-McCurdy cost breaches, resulting in the re-baselining of spending estimates.

The government should consider no longer following a procurement model that forces agencies to add funding to cover contingencies. This creates an abundance of ad hoc networks and solutions—with little thought given to affordability or efficiency and, even more importantly, sustainability. There has to be a cultural paradigm shift. Specifically, leadership has to commit to the recapitalization of federal SATCOM procurement.

The military faces intense competition for capital to fulfill modernization strategies while still dealing with the limitations of the Budget Control Act (BCA) of 2011 and an environment of continuing resolution (CR). Among an assortment of issues, this has posed increasing difficulties for initiatives in space, where new threats are driving changes in the US operating posture.

The upshot: Troops depend upon mobile, data-intensive apps. They do not care who "owns" SATCOM. They want results, in the form of superior capability, portability, flexibility and resilience. The existing procurement model fails to address their requirements.

A partnership will enable the DoD to augment capabilities while ensuring resilience in space, with seamless, satellite-driven mobility, connectivity and functionality. It will pave the path toward rapid and cost-effective innovation that is relevant to end-users' needs—*i.e.*, built to government's requirements, in contrast to the US government development cycle that is time-consuming and costly.

FORWARD STEPS

Fortunately, federal agency leaders and lawmakers are increasingly acknowledging this, voicing greater support for an entirely integrated SATCOM architecture: The ***National Defense Authorization Act (NDAA) for Fiscal Year 2017*** stands as a means to consolidate, streamline and improve SATCOM acquisitions. It calls for the Secretary of Defense to develop study guidance for an analysis of alternatives (AoA) for a follow-on wideband communications system to the Wideband Global SATCOM (WGS) system, which includes space, air and ground layer communications capabilities.

The study guidance would include the full range of military and commercial satellite communications capabilities, acquisition processes and service delivery models. Such assessment is focused upon the achievement of order-of-magnitude improvements in SATCOM capabilities.

The US Air Force has expressed a keen interest in bringing commercial operators into the analysis to determine the right way forward, rather than simply buying more DoD-owned satellite assets. As part of its analysis, the US Air Force is also exploring alternative business relationships with SATCOM suppliers rather than the historical and dated transponder leasing of the extended past.

In addition, the US Air Force announced that it plans to formalize the permanent creation of a commercial presence within the Joint Space Operations Center (JSpOC). This follows the launch of the Commercial Integration Cell (CIC) pilot program with JSpOC in 2015, one through which Inmarsat and five other satellite services companies—DigitalGlobe, Eutelsat, Intelsat, Iridium Satellite Communications and SES Government Solutions—have shared technology and information with the government on a no-cost basis.

After signing six Cooperative Research and Development Agreements (CRADAs), which enable industry and the government to share technology and information on a collaborative basis, industry has worked with JSpOC to increase integration and space situational awareness while enhancing the command and control capacity of the Joint Functional Component Command for Space (JFCC Space) under USSTRATCOM. The CIC has focused on the development of processes and commercial/government integration in conducting conjunction (or debris) assessments and addressing electromagnetic interference and resolution.

Lastly, President Trump and his team have made strong, forward-looking statements about space programs, emphasizing these programs as one of the administration's key interests. President Trump "*made space policy a major part of his final campaign message and Vice President Pence has been very enthusiastic about the role he would assume as head of the new National Space Council*," said former Pennsylvania Republican Congressman Robert Walker, a senior advisor to the Trump campaign and a former Chairman of the US House Science, Space and Technology committee. "*The council would help keep space issues front and center during the Trump Administration … its space policy puts a priority on reducing the vulnerability of our military space assets through use of multi-satellite constellations and new technology for servicing and refueling those constellations.*" According to *The Wall Street Journal*, President Trump administration's evolving space policy is expected to foster private investment.

COMPELLING CAPABILITIES

As leadership moves forward with such initiatives, we have already seen tangible, positive outcomes of commercially available, end-to-end capabilities built to government requirements.

To cite just a few examples, the following capabilities deliver increased interoperability among space, terminal and ground segments, at a much more affordable cost than the current acquisition model allows and at a much higher speed to market than MILSATCOM systems:

Space resiliency.
The military depends heavily upon satellites for global navigation and timing, communications and ground surveillance, among other operations. However, most of the military satellites were launched at a time when the space environment was considered

Artistic rendition of Inmarsat Xpress satellite.

benign. With today's adversaries able to jam satellites or shoot them down with ground-launched missiles, this is no longer the case. This speaks to the urgency for optimal resilience in space, through diversity, distribution and protection.

To achieve diversity, the DoD leverages industry partnership to access a wide range of constellations, frequency bands and functions, addressing different needs throughout different attributes and creating a robust, resilient environment in space and on the ground. Consequently, US forces can deploy systems from the military while gaining more capabilities—such as global mobility—from commercial operators. Distribution refers to the need to separate missions with distinctive purposes, so users are not entirely dependent upon a single satellite for everything—surveillance, communications, etc.

Available commercial resources lend assistance here too, as satellite companies can quickly integrate capabilities to support a range of tactical functions. Traffic is distributed within all commercial and military properties, so the mission proceeds regardless of which satellites are jeopardized by degradation or a threat. Another advantage: Because companies serve both public and private customers, they "muddle the target picture" for adversaries, reducing the incentive to compromise systems.

Private industry is setting standards for protection too, constantly hardening space assets not only for government customers, but for those in banking/finance, oil and gas, etc. To continue earning their trust, satellite companies are devoted to design, command encryption and a vigilant mission assurance posture. They are highly incentivized to defend satellites with the latest in proven anti-jamming mechanisms. They also pursue the proliferation of our space installations to boost redundancy—in the rare case that an adversary would compromise one, they have others that are nearby, interoperable and readily available on the orbital belt. Thus, the DoD mission endures without interruption, even if military assets are compromised.

Secure Networks.

Even while benefiting from COMSATCOM, government users access and control wideband capacity as part of their own independent network, in the same frequency band and WGS system. They have the option of connecting their military terminals through any DoD-certified waveform to the same destined Point of Presence, or through industry-provided secure enclaves. Either way, users are assured of authenticated Point of Presence in completely trusted locations, with vigilant network protection mitigating risk while safeguarding the enterprise.

In the process, industry obtains revealing insights into the types of responses available inside of government operations, along with a deeper understanding of national security implications. Subsequently, satellite companies adjust design elements and business strategies accordingly, paving the way for tactics, techniques and procedures (TTP) to function more effectively and safely in this diverse environment.

Though a fully realized partnership, servicemen and women view satellite communications with the same sense of readily available utility. They control what capabilities they obtain, instead of being "assigned" to whichever technologies that a particular government authority provisions to them. They gain entry to a diverse range of functionalities and spectrum assets, with a massive volume of bandwidth. As a result, users reap the mission-supporting rewards of exceptional capability, capacity, redundancy, diversity, protection, scalability and global portability. The disparate, stove-piped SATCOM procurement procedures will fade away as a forgotten relic, and we will continue to advance augmentation efforts as we move forward.

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Rebecca M. Cowen-Hirsch is Senior Vice President for Government Strategy and Policy at Inmarsat, the leading provider of global mobile satellite communications. Ms. Cowen-Hirsch is responsible for establishing Inmarsat's strategic direction and policy, and leads the company's shaping of its US government focused capabilities and partnerships.

FLEXIBLE NEXT-GENERATION FDMA TECHNOLOGIES DRIVING BIG COST SAVINGS

By Tony Sewell, Senior Manager, Product Management, DataPath, Inc.

The last 10 to 15 years has seen significant advancements in satellite networking waveforms and technologies, driving tension and divergence between the leading frequency division multiple access (FDMA) and time division multiple access (TDMA) technologies.

Certainly, both TDMA and FDMA, which encompasses single and multiple channel per carrier waveforms (SCPC and MCPC), have strengths and weaknesses that depend on the particular network topology being implemented; however, it's not the objective of this article to debate these well-known characteristics.

There has been significant pressure for government and defense networks to move towards IP-based TDMA systems to deliver greater deployment flexibility, capacity sharing, and, hopefully, operational expenditure savings. However, there recently have been ground-breaking developments in FDMA technologies that are unlocking significant capital and operational expenditure savings opportunities, while also delivering greater network planning flexibility and adaptability.

The purpose of this article is to examine the application of such technologies to government C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance) missions. These technologies offer great promise to networks that are reliant on very high data rate exchange, advanced spectral efficiency and provide affordable and highly flexible alternatives to capital-intensive TDMA networks for more modest sized networks.

With their respective experience in deployed satellite communications terminals and networks, and advanced waveform and modem development, DataPath and Datum Systems have collaborated to deliver such powerful new network solutions to military users. Presented are two examples to demonstrate the flexibility and potential of these technologies.

POINT-TO-POINT AND POINT-TO-MULTIPOINT TOPOLOGIES

Commanders on the modern battlefield are challenged by ever increasing data rate requirements, as well as nodes with vastly different information requirements and RF characteristics. Joint operations are the norm, and particularly for expeditionary and special operations forces, a single network will see data exchange between maritime, air and land-based nodes.

Figure 1 provides an example of such a network. In this case, a DataPath DKET3400 terminal (4.0 meter deployable Earth station) is providing a hub capability, supporting a point-to-multipoint network for numerous land-based terminals (DataPath CCT200 2.0 meter transportable terminals and MT90 0.90 meter man-pack terminals), and a UAV. Deployed with DataPath's Advanced Tactical Modem (powered by Datum Systems), the field commander can leverage a number of cutting edge capabilities in a unified network.

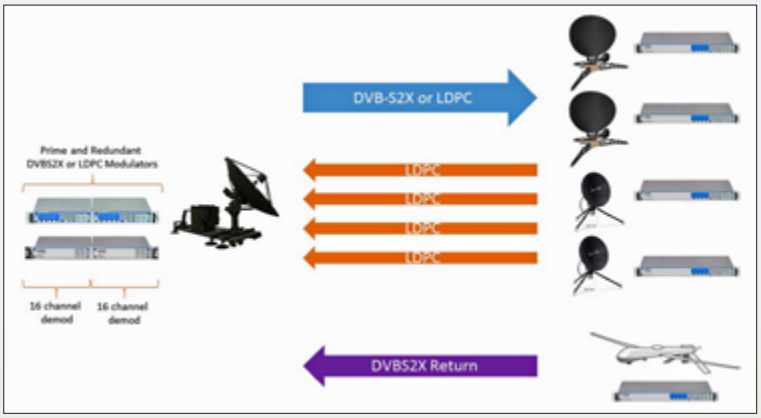

Figure 1. DataPath Advanced Tactical Modem supporting Point-to-Point and Point-to Multipoint high data rate, multi-waveform network topology

FLEXIBLE TOPOLOGIES

This is an example of a hybrid network deploying a TDM (Time Division Multiplexed) DVB-S2X outbound and land-based SCPC return channels. The use of a TDM carrier from the hub provides the ability to transmit much higher data rates to remote nodes (up to 350 Mpbs) as well as leverage advanced adaptive coding and modulation schemes, all the while realizing statistical bandwidth savings by using a single DVB-S2X outbound carrier instead of individual SCPC transmit links to remote sites, as well as rack space savings and SWaP (Size Weight and Power) savings.

The modulator deployed in the hub terminal requires only 1 RU of rack space (primary and redundant), as compared with a traditional SCPC point-to-point rack configuration that requires as much as 10 RU for this network example to provide primary and redundant links.

Another unique feature of this technology is the ability to insert the waveform most appropriate to the specific mission profile. In this example, an unmanned vehicle employs a DVB-S2X return channel to transmit very high data rates generally not available in remote terminals, whether FDMA or TDMA. As a software defined modem platform, DataPath and Datum are developing a TropoSat feature, allowing the integrated terminal to be deployed in troposcatter mode to support very high data rate terrestrial networks. This feature will be enabled in the DataPath modem, allowing the commander flexibility in the field to choose the desired mode of operation.

SPECTRAL EFFICIENCY

Throughput maximization and bandwidth efficiency is realized through the employment of some key technologies within this network. The introduction of the DVB-S2X waveform represents a huge step change advancement over the legacy DVB-S2 technology widely in use, providing a much larger range of flexible and efficient MODCOD (modulation and coding rates) options.

The modems at the remote sites leverage the unique Datum-powered FlexLDPC waveform, delivering the industry's most spectrally efficient LDPC channels with granular code rate and block size selections to provide a new level of fine-tuning to optimize throughput and minimize latency.

Additionally, the modems employ SharpCarrier, a state-of-the-art Low Excess Bandwidth (Alpha) Filtering technology, which allows network managers to significantly reduce the guard bands associated with channel spacing.

Legacy SCPC waveforms require channels to be spaced (on average) at about 1.35 times the symbol rate. SharpCarrier allows carriers to be spaced as low as 1.05 times the symbol rate, providing an immediate spectral efficiency increase of 28.5 percent and bandwidth savings of 22 percent. This translates into potentially significant OPEX savings on commercial bandwidth leases.

IP TRAFFIC MANAGEMENT AND OPTIMIZATION

For network planners, implementing efficient bandwidth plans is only part of the challenge. Satellite links with high latency also provide challenges to IP traffic flows. DataPath's modems implement modular network interface options to match the requirement for different network interface protocols, software defined IP acceleration and compression, and advanced QoS for effective traffic management.

When implementing an Advanced IP Interface module, remote terminals can support IP throughput of up to 150,000 packets per second. Additionally, IP interface modules can support the low latency demands of 3G, 4G and LTE networks, gaining greater recognition in government networks.

RACK UNIT DENSITY

SCPC networks have traditionally been extremely resource intensive at hub sites, requiring at least 1RU per point-to-point connection. Not only is this important in the physical capacity sizing of the hub site, but it's also potentially prohibitively expensive, with advanced SCPC modems often running into the many tens of thousands of dollars.

Figure 1 illustrates the power of DataPath's solution, capable of demodulating 16 channels per 1/2 RU. So in this example, with 2RU of space in the DKET3400, a network of up to 32 individual remote sites can be supported. This is a huge economical advantage. When combining the capital savings in terms of physical modems and rack space required to terminate a network, with the spectral efficiency offered through protocols like FlexLDPC and SharpCarrier, the combined OPEX and CAPEX savings are significant.

For planners deploying smaller networks where a costly field deployable TDMA system may have previously been considered, DataPath's solution provides a compelling alternative.

MESH NETWORKS

As TDMA networking has become more popular in the tactical arena for many reasons, including bandwidth efficiency for large networks, improved network management, and the ability to push remote terminals closer to the front lines of deployed operations, the capability to mesh tactical SATCOM networks has diminished.

For the traditional Hub-Spoke TDMA network, mesh is a difficult technical implementation that has been discontinued by many modem manufacturers. That leaves SCPC as the only alternative, though it has been seen as inefficient in terms of the number of modems required to support it, as well as bandwidth requirements.

Figure 2, however, illustrates how DataPath's high-density demodulation hardware makes the opportunity to implement mesh in the tactical arena an attractive and economical option again.

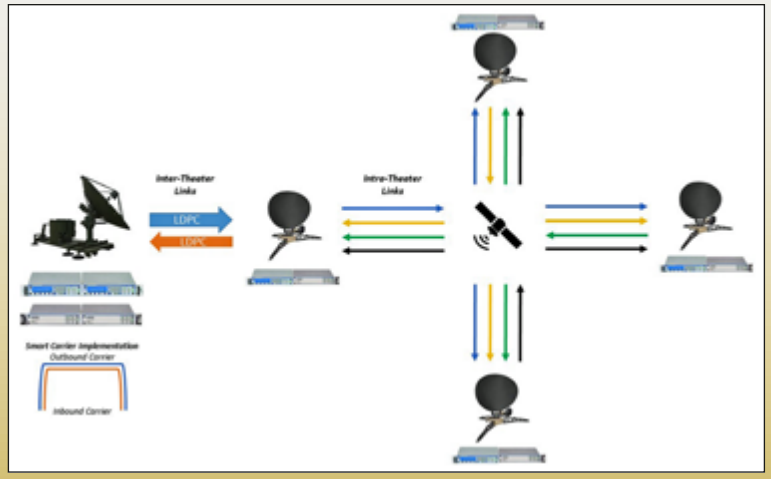

Figure 2. DataPath Advanced Tactical Modem supporting efficient mesh topologies, as well as SmartCarrier cancellation technology application.

There are many reasons to mesh. Many applications implemented in the modern area of operations don't perform well with the latency associated with more than one satellite hop.

A number of global militaries, such as the US and Australia, still rely on mesh connectivity between larger nodes to optimize applications such as voice, video, battlefield command systems, and other such applications. While *Figure 2* illustrates a mesh network between four terminals, the DataPath modem supports up to 16 individual mesh channels within a single rack unit of space, providing spectrally efficient, high data rate mesh links between nodes. For network planners, this provides yet another

option for deployment flexibility, depending on the mission profile for intra-theater communication.

SMARTCARRIER

Figure 2 also illustrates a unique technology called SmartCarrier for the inter-theater link. SmartCarrier is Datum-powered carrier cancellation technology to allow two carriers between nodes to occupy the same bandwidth, assuming both sites can view the combined downlink.

What is unique is that the 'cancellation' is conducted in the base band, instead of requiring the IF signal to be sampled and digitized, eliminating considerable modem hardware and cost. With the feature built into the modems, network planners can implement bandwidth savings throughout the network.

INTEGRATING CAPABILITIES

Integrating hardware and management tools is the final crucial step in deploying the DataPath solution. From a hardware perspective, the modem technology is highly modular, built on a series of flexible printed card assemblies for waveforms and data interface protocols.

The modems are also software definable, adding an additional level of flexibility and scalability. This modularity provides the ability for network technicians to easily alter network configurations or maintain equipment more economically than is usually seen in modem technologies.

The modem modularity, as well as the very low SWaP (Size Weight and Power) footprint, enables flexible integration into portable and mobile terminal platforms, to perform efficiently in the harshest of environments. The modem technology is also able to support operation in static and mobility platforms, supporting direct spread spectrum capabilities on LDPC and DVB-S2X waveforms, for more advanced applications.

Finally, these advanced modem, baseband and terminal systems are all characterized by a range of sophisticated management tools. In order to make the management, monitoring and control of the network components more intuitive and efficient, DataPath integrates its powerful MaxView® Enterprise™ software providing a highly scalable and customizable capability to remotely manage the entire network.

Figure 3, displayed in the next column, provides an overview of the scalability of MaxView, integrating and providing management and control at the device, service and network levels. DataPath's Advanced Tactical Modem platform has an ultra-efficient Modem Control Channel (MCC), enabling MaxView's powerful remote monitoring, control and management capabilities of the entire deployed network.

Not only does this provide situational awareness and greater network control, but also the ability to provide more sophisticated remote engineering and trouble-shooting at remote sites, where there may not be skilled technicians deployed. This delivers greater flexibility for communication planners, and for commanders to push sophisticated technologies further towards the forward edge of the operational area.

Figure 3. Illustration of MaxView Enterprise monitor and control software scalability across network levels.

CONCLUSIONS

DataPath's solution, powered by Datum technologies, provides one of the most sophisticated, efficient and cost-effective network capabilities to the modern area of operations.

The combination of features and flexibility allows capability managers and network planners to have a closer look at the current norms in their deployed C4ISR systems, and explore a range of new and flexible deployment topologies, which promise to bring unprecedented capital and operational expenditure savings to tight government budgets.

datapath.com/

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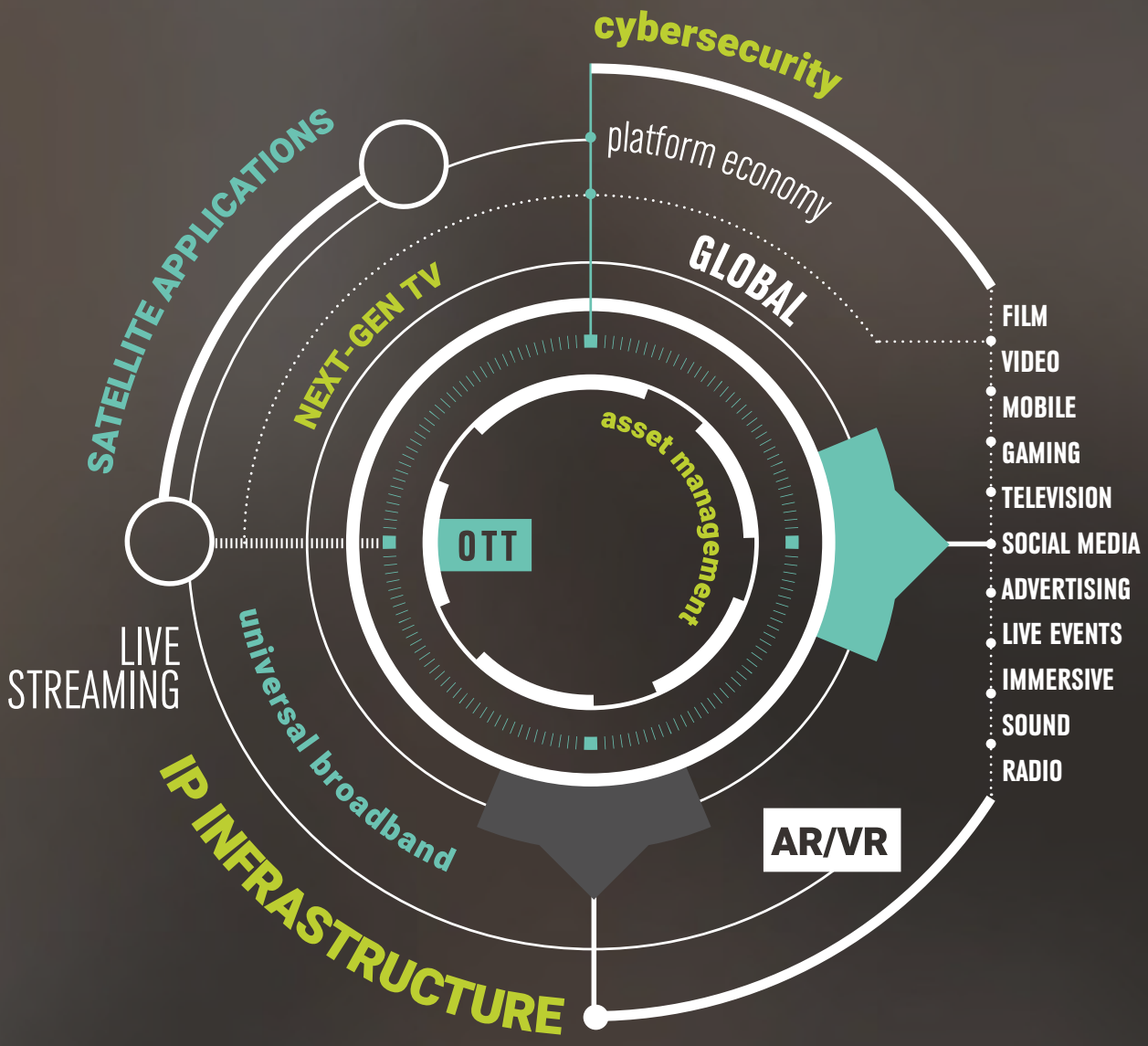
DataPath's CCT200 Fly-Away® antenna.



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LET'S THRIVE.

DoD and Commercial, Protected SATCOM Convergence and End-to-End Protection

By Steve Williams and Chris Badgett, Business Area Managers, RT Logic, a Kratos Company

From a commercial perspective, SATCOM is used for critical national infrastructure services such as communications, financial and banking services, power grid operation, security, healthcare, transportation, disaster relief, and essential distribution systems for food, water, medicine, fuel and vital products.

From a DoD perspective, SATCOM is indispensable to command, control, reconnaissance, relief and warfare communications. As SPAWAR PMW/A 170 asserts, "*Bandwidth is **THE** Key enabler of Information Dominance.*" For the US Navy in particular, SATCOM is the mainstay of long distance communications in peacetime, for humanitarian operations and especially when on wartime footings.

SATCOM demand is ever increasing in response to unprecedented international data requirements from the human, military and financial sectors. This extraordinary demand is driving a convergence of commercial and DoD SATCOM requirements.

Increasing Bandwidth Availability

The US Navy is experiencing steep SATCOM bandwidth growth. Even as new satellites come online, their bandwidth is immediately consumed, with requirements continuing to outrun bandwidth availability. Among many results, this leads to increasing utilization of commercial satellites to carry encrypted Navy communications within Commercial Broadband Satellite Program (CBSP) capabilities.

Commercially, SATCOM bandwidth use doubles every two to three years. In commercial space, this growth generates revenues that can, in part, accrue to new satellite development and launch. Even so, staying ahead of the SATCOM bandwidth demand curve is a daunting task.

In addition to deploying more satellites to meet growing bandwidth needs, the SATCOM market is also vigorously pursuing increased bandwidth utilization efficiencies as well as capabilities which support dynamic reallocation of available bandwidth. The rapid evolution and deployment of High Throughput Satellites (HTS) will supply additional available bandwidth, and requires budget availability to conduct needed R&D, construction, launch and upkeep operations. Additionally, advanced modem technologies leveraging concepts from Adaptive Coding and Modulation (ACM) techniques, wide band frequency hopping, direct sequence spread spectrum and other bandwidth-sharing and interference-resistant technologies will be important.

Improved SATCOM Planning

As bandwidth becomes more available, the planning process for satellite, transponder and frequency procurements, authorizations and assignments must also keep pace with military and business needs. However, SATCOM planning isn't consistent or shared across the commercial and DoD space, can employ antiquated manual techniques and tools, involves numerous people in the control loop, and is often error-prone.

In peacetime, current planning processes for requesting SATCOM access can be time-consuming, non-agile and frustrating. Additionally, the process of reporting interference events or other outages into SATCOM planning operations is often manual, incomplete and overly burdensome for both the SATCOM user and the planner.

Automated SATCOM planning and re-planning systems operating at electronic speeds, quickly adapting to dynamic bandwidth availability, smartly avoiding interference, and automatically adjusting equipment and settings at both ends of the SATCOM link must be developed and deployed. These systems will greatly facilitate operations in degraded environments, will provide badly needed fail-over capabilities, are a key to success with rapidly expanding VSAT systems and related interference protection, and may themselves deter many forms of intentional interference.

Reliable Protected Communications

"*Protected Communications*" is a general phrase representing actions taken beyond the normal SATCOM transmission to reliably transmit and receive signals. Protected SATCOM extends well beyond typical approaches related to increasing the overall link budget (e.g. larger apertures, more power, changing modulation types, etc.).

For the DoD, Protected MILSATCOM is often implemented by an EHF service with small-footprint SATCOM beams for strategic and tactical purposes.

- *Strategically, Protected MILSATCOM must provide low probability of interception, detection and exploitation (LPI, LPD and LPE) and be survivable, to include anti-scintillation and anti-jam communications. Strategic Protected MILSATCOM must also provide robust command and control services in benign, contested and nuclear operational environments, as shown in Figure 1 below.*

- *Tactically, Protected MILSATCOM must provide anti-jam and LPI/LPD/LPE communications in both benign and contested environments.*

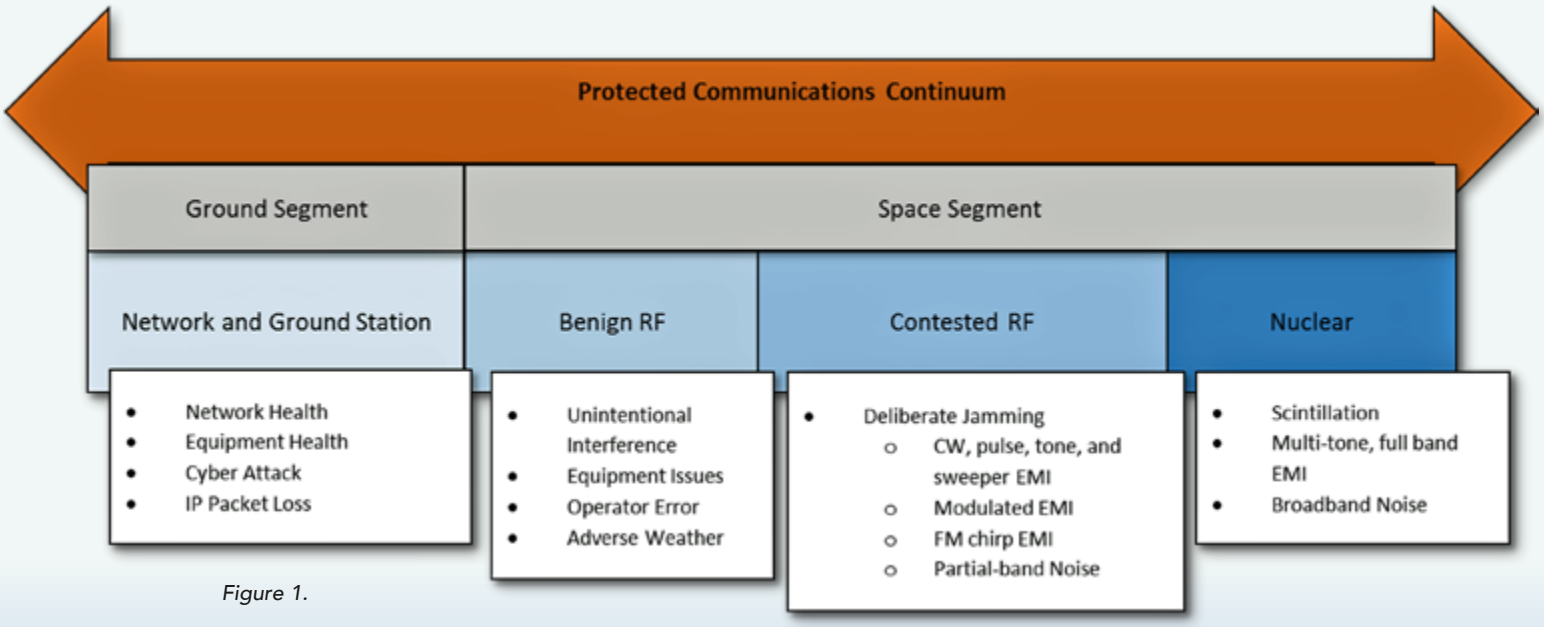

Figure 1.

For the commercial segments, Protected Communications attempts to minimize the effects of interference in benign environments, though recent events also suggest the need for anti-jam capabilities.

In all cases, the Terrestrial Network and Ground Station must be resilient to growing Cyber Attack threats and must monitor and automatically compensate for overall network and equipment health issues as well as data communications losses, to include economical antenna site diversity and rapid failover

Generally, advanced systems, products and capabilities along the Protected Communications Continuum fall within a Protection Progression evolution as shown in ***Figure 2***—Protection Progression for products, capabilities and advanced systems.

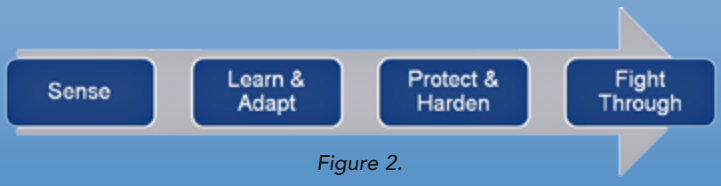

Figure 2.

From a threat sense perspective, users and systems must quickly know when something is wrong and when communications are being degraded or interrupted. For example, for RF signals, automatic signal monitoring with real-time interference detection, characterization and reporting is a desired approach. For networks, network health monitoring, cyber-attack sensors and virus detection are good approaches.

Learn and Adapt tools provide insightful data trending and analysis that feeds understanding and automatic adaptation to the threat and risk occurring in the environment over time. Effective data logging and monitoring should store historical, time-tagged measurement data to support trending and analysis. Such a repository is useful for predicting equipment failures, communications outages, and impending electronic attack preceded by detectable signal trends and other indications. Historical data can also be exploited to differentiate equipment problems from operator error, and between accidental or intentional interference.

Protect and Harden is the next line of protection, and includes solutions that protect against threats. Signal geolocation capabilities fall within this classification, as do devices that protect against cyber-attack or network transmission issues.

Fight Through capabilities utilize advanced signal processing, for example, to add robustness at the waveform level to enhance LPI/LPD/LPE. Wide band Frequency Hopping and Direct Sequence Spread Spectrum (DSSS) are typical methods to permit operation during active interference and jamming. Also from a fight-through perspective, the Protected Tactical Waveform (PTW) is a new approach using Frequency Hopping Spread Spectrum (FHSS) to provide enhanced anti-jam attributes. PTW combines features of the current MILSATCOM protected waveform and the commercial waveforms such as Digital Video Broadcasting (DVB.) This hybrid strategy strives to balance protection and affordability.

BEST PRACTICES FOR END-TO-END PROTECTED SATCOM

Numerous systems, capabilities and technologies exist or are in active research and development toward the end goal of protected SATCOM. Many are already in dual DoD/Commercial use, or are rapidly converging for use within both domains. Many align with best practices for end-to-end protected SATCOM. Here are a few examples...

- *Designed-in Protection*
- *Ground System Protection*
- *Signal Monitoring*

Designed-in protection

RF link protection begins long before a satellite is launched or a ground station is designed. Channel Simulators, Transponder Simulators and Satellite Signal Emulators can generate nominal and worst-case SATCOM test signals within a controlled lab environment. Engineers can then design and tune their firmware, software and hardware for unimpeded communications even under degraded signal conditions.

These instruments give SATCOM hardware, firmware and software designers a huge advantage during the design and test process, enabling them to develop and test equipment that will be tolerant of natural signal degradation and resilient to a broad variety of attacks on the signal.

SATCOM gear should include embedded signal monitoring and interference cancellation/reduction capabilities. These functions must communicate with higher-level systems to provide overall RF situational awareness, and resilience.

Ground system protection

IP traffic between ground system components and sites must be fast and reliable. However, wide area IP networks exhibit traits that can degrade performance: dropped packets, indeterminate latency, variable jitter, and packet duplication and reordering. For most users, Transmission Control Protocol/Internet Protocol (TCP/IP) masks these problems and delivers data acceptably. But many mission critical applications cannot tolerate TCP/IP's retransmit and acknowledge behavior when attempting to deliver consistent data at required rates.

To repair dropped packets, Packet Forward Error Correction (PFEC) and Intelligent Retransmission Protocol (IRP) protocols should be utilized. Both protocols allow high throughput with low latency across lossy, long-haul links and give the user the flexibility to choose the best solution for each situation. Ground systems must provide extensive network performance analysis and diagnostics in addition to robust traffic protection.

Automatic selection and fast switchover between geographically separated antennas should be available to ground stations. Enabled by advanced and very cost-effective RF over IP transport devices, such diversity compensates for SATCOM-impairing weather, interference or failure events. This capability also addresses equipment, manpower and security concerns.

Signal monitoring

With well-designed and tested SATCOM systems enhanced for link protection, the first operational line of defense is continuous and advanced monitoring of the received and transmitted signals. Automatic signal monitoring must go beyond simple spectrum analyzer mask analysis of bandwidth, center frequency and power level. In-depth and real-time signal analysis must also include blind determination of modulation type, data rate, coding scheme, MER, EVM and BER.

External and embedded monitoring and analysis tools should mathematically decompose the signal of interest in real-time, and search for unauthorized signals within the protected bandwidth that could degrade QOS as shown in *Figure 3*.

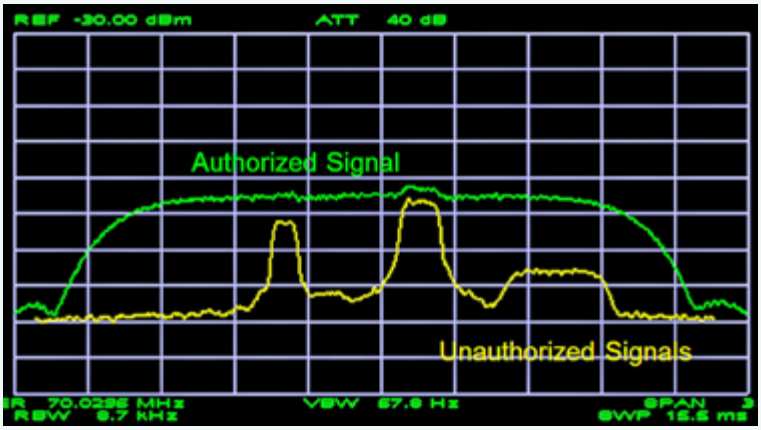

Figure 3: Advanced Spectrum Analysis with covert and overt interference detection and characterization capabilities.

As well, these tools should measure signal parameters (*e.g.*, modulation type, data rate, bandwidth, center frequency, BER, Es/No, etc.), and automatically alert operators and systems of discrepancies from the Satellite Access Authorization (SAA), as well as detected interference.

THE VITAL INFRASTRUCTURE ELEMENT

Protected SATCOM refers to a wide area of need with a broad set of existing and evolving solutions that leverage capabilities between DoD and Commercial applications. SATCOM is a vital infrastructure element in commercial, as well as military C2 and data transport applications. Due to their customer-critical and mission-critical nature, the function and performance of these SATCOM links must be protected with sharp focus and constancy.

This article has summarized just some of the best practices that can be employed to assure mission success. For more information, please see *Best Practices for End-to-End Protected SATCOM* in the June 2016 issue of *MilsatMagazine*.

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GEOLOCATION METHODS OF SATELLITE TRANSMITTERS USING A SINGLE GSO SATELLITE

By Erwin Greilinger, Sales and Product Line Manager, Siemens Convergence Creators

The increasing demand for satellite communication links has led to an increasing number of satellite signals as well as an increase in the amount of interference as a result of poor installations and misdirected antennas.

Another reason for increased interference are acts of terrorism and political turmoil, such as the systematic disturbance of western broadcast television in the North African and Near East region as well as in countries such as Egypt, Syria, Libya, and Iran.

Satellite operators are becoming increasingly interested in solutions that detect interference, the main task of a satellite monitoring system, but also to localize its source, *i.e.*, to geographically localize, or geolocate the transmitting station of an interferer. However, most localization systems have a crucial drawback: They need to receive the interference signal via two adjacent satellites in order to perform geolocation [1, 2, 3, 4, 5].

Another approach uses crosstalk measurements between signals received from multiple antennas/beams belonging to the same satellite [6, 7], and it has also been shown that frequency measurements of signals from a single satellite, taken at different times, can be used to locate an unknown emitter [8, 9].

Currently, the most promising approach able to localize the source of an interferer using a single satellite is based on the variation of signal strength with time. This technique relies on the fact that the signal strength of a carrier varies with time due to a number of factors, including movement of the satellite, atmospheric and weather conditions, and changes in power amplifier gain and antenna alignment at the uplink station. It turns out that there are similarities in the patterns of variation of signal strength for carriers originating from the same geographical area. This method is the subject of an Austrian patent [10].

This article describes the concept and pros and cons of available methods able to localize the source of an interferer using a single geostationary (GSO) satellite.

PROBLEM DESCRIPTION

At present, there are commercial geolocation systems from different manufacturers available, all these systems use time and frequency difference measurements from two GSO satellites.

Geolocation of radio transmitters affecting communication satellites in GSO orbit is a challenging task which is usually accomplished through analysis of time difference of arrival (TDOA) and frequency difference of arrival (FDOA) compound measurements.

The main drawback of these geolocation principles is their necessity of having at least two satellites, which are close enough to each other, in order to have useful crosstalk energy on the adjacent satellite for the calculation. Even though several hundreds of GSO satellites are in operation from the main satellite operators, some of them are still "isolated", meaning that the next adjacent satellite is separated more than 10 degrees.

In this case the crosstalk is very likely too small in order to be measurable. Even in case an adjacent satellite is available, that does not necessarily mean that it can be used for geolocation.

One of the main parameters which need to be known by geolocation systems is the exact position and velocity of the satellite (for both, the main and the adjacent satellite). These parameters are called satellite ephemeris data which have a significant impact on the accuracy of geolocation systems. In case the adjacent satellite is from a different satellite operator, such ephemeris data are often not known, or only with an accuracy which makes geolocation useless.

With the help of tracking systems you could calculate the ephemeris data from satellites even though no ephemeris data are available. But one of the preconditions of successful tracking is the availability of enough reference stations.

A reference station is a known uplink station in terms of its localization (Latitude. Longitude), which transmits a known (reference) signal to the satellite to be tracked. Needed are at least five to six reference stations in order to calculate the ephemeris data with sufficient accuracy. That sounds easy but means in reality a real challenge and is often impossible to achieve. The reason is that the operators often do not know from which station what signal is being transmitted.

Should you be lucky enough to have an adjacent satellite available which is close enough to your affected satellite and you also know its ephemeris data very precisely; the next hurdle is that the crosstalk on the adjacent satellite needs to be in the same frequency area and polarization as from the interference signal on the main (affected) satellite.

Taking all that into account, you can imagine that there are a lot of scenarios where geolocation is impossible with the current available tools and algorithms. Therefore, it would be a big advantage of having a geolocation system available working by just receiving the interference signal via a single satellite.

Geolocation method using a single GSO satellite and inverse Doppler shift Section 5.1.2.8 of [11] already describes a possible method for geolocation of an unauthorized transmitter on Earth by using a single GSO satellite. This method makes use of the small Doppler frequency shift caused by the motion of a GSO satellite for determining the transmit location of an unauthorized transmitter.

The application of Doppler created by a single satellite for geolocation has been used previously for satellites in the lower orbits, which have significant motion with respect to Earth and their position changes at different times. Hence, the large motion of these LEO satellites creates a significant and easily observable amount of Doppler frequency change. The Doppler frequencies at several time instances can fix a ground emitter. Indeed, this is the technique adopted in the search and rescue satellite (SARSAT) localization system.

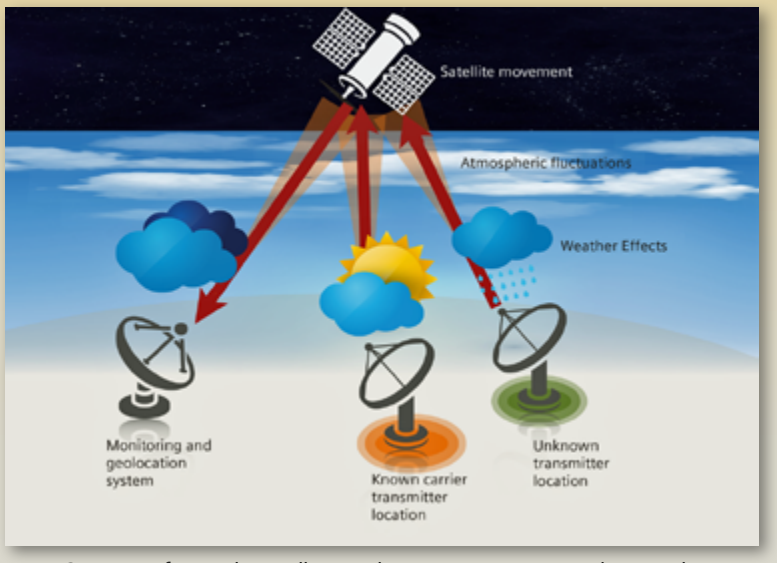
The use of Doppler from a single GSO satellite for the purpose of localization is not straightforward and is a much more challenging problem. This is because the motion of a GSO satellite with respect to the Earth is by nature very small and the resulting Doppler shift is also very small and much more challenging to accurately observe. In addition, the use of Doppler is further complicated by the fact that the uplink frequency of the ground emitter is unknown, the exact frequency of the satellite local oscillator is unknown and the satellite ephemeris data can have significant uncertainty in the satellite position and velocity [8].

Another drawback of this approach is its sensitivity to frequency variations caused by the uplink station HW itself *(e.g.*, frequency sources and PLL equipment being affected by temperature variations, etc.) which easily can reach or even exceed the influence of the Doppler shift.

In fact, geolocation systems on the market using this method have shown that the reachable accuracy is beyond 100 km and therefore not really useful to identify the uplink station of an unauthorized transmitter. They may work with acceptable accuracy when the interference signal is received via an inclined orbit satellite, which shows greater movements compared to regular GSO satellites, resulting in a bigger Doppler shift.

USING A SINGLE GSO SATELLITE

This technique relies on the fact that the power of a satellite signal, transmitted from a certain uplink station on the Earth to the satellite and down to a receiving station, varies with time due to a number of factors, including movement of the satellite, atmospheric and weather conditions (on the uplink and downlink side), and changes in power amplifier gain and antenna alignment at the uplink station—see *Figure 1*.



Concept of a single satellite geolocation system using the correlation against known transmitter method.

It can be assumed that signals transmitted from the same uplink station or the same geographical area show the same power variations in the same time frame, whereas signals transmitted from different geographical areas will show different power variations in the same time frame.

The following example in *Figure 2* at the top of the next column shows the power variations of two signals (red and blue) transmitted from the same uplink station over a period of four days. A 24 hour variation coming from the satellites movement can be clearly identified.

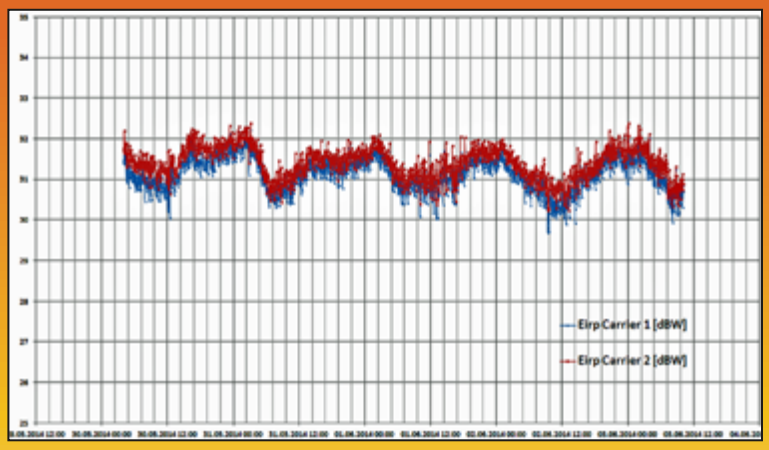


Figure 2.

Figure 3 shows an example of power variations caused by weather effects (big spikes). In both cases the power variations are more or less identical since both signals are transmitted from the same uplink antenna.

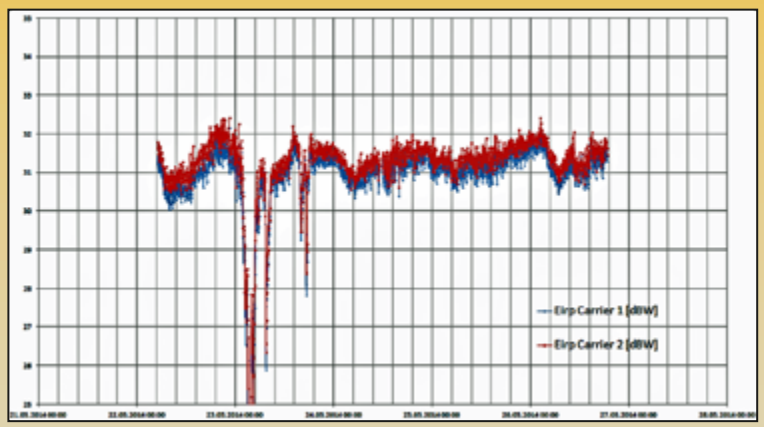


Figure 3.

In order to find the transmit station of an interfering signal, one has to calculate the similarities of the interfering signal with other known signals. This is usually done in the frequency domain by correlating the signals or parts of them. Therefore, the correlation algorithm is most crucial to geolocate the interferer in terms of accuracy, efficiency and success.

This concept is applicable in case a number of different signals are transmitted from the same uplink station or in the same geographical area as the interference signal. All signals (including the interferer) could be permanently monitored by a carrier monitoring system (CMS) and any change of the interfering signal in power, frequency or bandwidth (*e.g.*, forced by weather influences) is tried to be correlated with the measurements of other signals investigated. In case of a positive correlation caused by e.g. weather influence, HW dependencies, etc., it can be assumed, that the uplink location of the interference signal is identical or close to the uplink location of the known carrier.

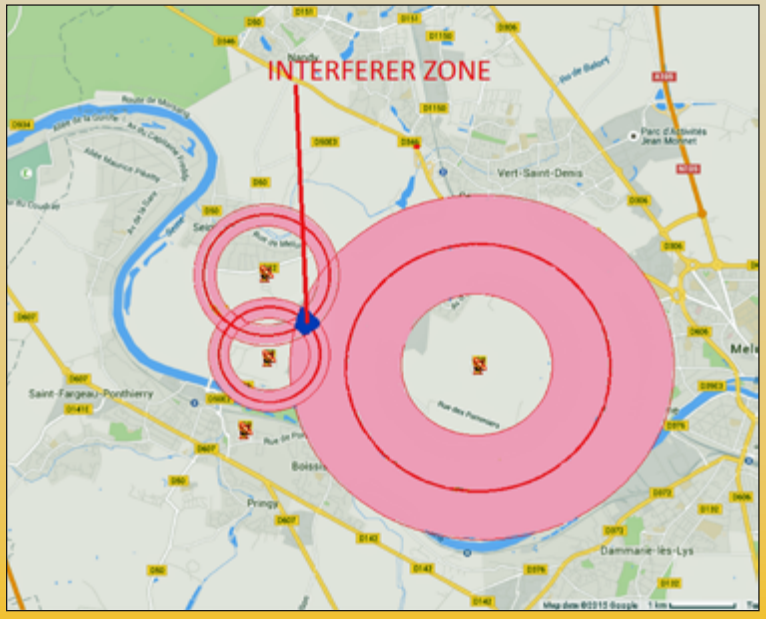
The challenge in this method lies in the correlation approach since the measurements are typically not performed at exactly the same time depending on the monitoring strategy (e.g. Round-robin). This influence is supposed to significantly affect the correlation result requiring relevant measures (time delta depending weighting, plausibility checks, ambiguity mitigation, etc.) to be investigated. Furthermore, the method could be enhanced in terms of taking into account additional information such as HW

related information belonging to the known transmit stations, third party weather information, etc. For example, weather information could be used for additional ambiguity mitigation in terms of identifying/eliminating cases which are in conflict with certain weather situations.

Based on this concept, Siemens Convergence Creators has developed the single satellite geolocation system SIECAMS ILS ONE using techniques from quantum information theory. The system computes a signature, which represents the EIRP variations for a carrier from a particular period of time.

SIECAMS ILS ONE defines a distance measure to numerically quantify the degree of similarity between two signatures, and by computing the distance between the signature for an interfering carrier and the signature for each carrier in a database of known carriers, the carrier with the closest distance can be identified to the interfering carrier. In other words, this identified carrier needs to be transmitted from the same geographical area as the interfering carrier.

In case the transmit location in terms of latitude and longitude of the identified carrier is known, the geographical area can be drawn as a circle, with a radius representing the distance value, on a map. The accuracy of the system can be increased in case several carriers with a similar signature and therefore with a close distance to the interfering carrier can be identified and visualized as different circles on a map as shown in ***Figure 4*** below. The intersection of the different circles represent the very likely position of the transmit station of the interfering carrier.



In this article, two currently available methods for geolocating a satellite interference signal via a single GSO satellite have been described. The method using the Doppler shift has the clear disadvantage in its sensitivity to frequency variations which are often caused by the uplink station HW and which are overlaying the very small Doppler shifts caused by the motion of GSO satellites resulting in an unacceptable accuracy. It may work when the interference signal is received via an inclined orbit satellite, which shows greater movements compared to regular GSO satellites.

The second method realized in the SIECAMS ILS ONE product from Siemens Convergence Creators, which makes use of the signal power variations caused by the movement of the satellite, atmospheric and weather conditions, could already prove its usefulness for satellite operators by successfully localizing interference signals which could not be localized by traditional geolocation systems working with two adjacent satellites.

In the best case, the system can identify the uplink antenna of the interference signal in case other carriers are transmitted from the same antenna at the same time. In other words, the system can reach an accuracy of 0 (zero) meters! In addition a significant improvement in accuracy and reliability has been achieved by applying statistical analysis methods to continuous measurements, making the entire system more robust by eliminating interfering downlink effects.

SIECAMS ILS ONE was developed with the vision of realizing the best possible quality of service for all users of satellite communication. In the context of this philosophy, Siemens Convergence Creators takes their responsibility seriously by regularly delivering improvements of the solution's capability to help operators pinpoint interference sources.

convergence-creators.siemens.com/satellite-testing-and-monitoring.html

Erwin Greilinger is Sales and Product Line Manager for Siemens Convergence Creators' Satellite Communication and Monitoring Solutions. Thus he is responsible for the definition of products for monitoring and troubleshooting the quality of satellite communications systems, product marketing, technical and commercial sales activities. Prior to joining the Siemens Space Business, he was section head for Broadband Management Systems and Fast Internet Solutions. This business sector handled projects in the area of Cross Domain Management Systems especially for Broadband IP and ATM networks. He holds a degree in Electrical Engineering from the Federal Secondary Collage of Engineering in Vienna, Austria.

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HITTING THE SPOT FOR GOVERNMENTS AND NGOS

By Gavan Murphy, Director of Marketing, EMEA, Globalstar

In a competitive environment, businesses strive to be more innovative and work harder to make their budgets stretch further—this same ethic applies to government departments and emergency services agencies, particularly today as they are called upon to get involved in ever more diverse operations and crises.

As UK, French, Spanish and other NATO forces continue to set up mobile headquarters and command operations in new locations around the world, they increasingly rely on communications to carry out their roles and to co-ordinate with fellow organizations. However, if they are in a region with little or no alternative infrastructure, and/or unreliable GSM network coverage, their challenges are compounded. They need the flexibility that only new types of mobile communication tools can deliver, to reliably convey voice and data, and also for better, more wide reaching tracking, safety and security.

Procurement officers in all kinds of non-commercial agencies are discovering that bypassing more expensive B2B communications solutions in favor of lower cost consumer devices can help them manage their budgets and get the reach and reliability they need. At the same time, there is growing recognition of the need to safeguard staff, whether those personnel are carrying out their roles on the frontline or in the back office.

Since Globalstar launched the SPOT family of devices back in 2007, they have played a role in 5,000 rescues around the globe. The company has gained a reputation for providing state-of-the-art tracking and enhanced safety for adventurers. Over the last few years we've also seen the steady uptake of SPOT among military organizations and other government-backed agencies around the world, as emergency support is provided to the public, particularly following man-made or natural disasters.

With many consumer devices designed for rugged environments, military organizations are making a smart decision when they adopt consumer satellite communications (SATCOM) and asset tracking capabilities to help run their operations more effectively and better manage their assets and personnel.

MEETING GOVERNMENT AND MILITARY NEEDS

The unique and rigorous requirements of military and civil protection organizations have led Globalstar to develop modifications that make SPOT and its capabilities even better suited to their specific needs.

Close collaboration with armed forces customers on product designs and product utility have enabled SPOT technology to deliver ever-increasing levels of functionality. As a result of these efforts, SPOT is proving increasingly popular with government agencies, first responders as well as NGOs.

One example of how the military is using consumer devices is Spain's Ministry of Defence (MoD). In 2012, the MoD's personnel operating in remote locations with no cellular coverage started using SPOT satellite messengers.

There are now hundreds of low-cost SPOT devices in the field, enabling MoD field personnel to communicate with central command for fast recovery in case of an emergency, as well as ongoing tracking of personnel and assets.

THE IMPORTANCE OF MAPPING INNOVATION

Additional good news for governments and their agencies is that there are a number of specialist resellers and VARs driving innovation in mapping and geospatial-based technologies, making our devices even more useful in military and other first responder contexts.

UK-based Mapyx, for example, helps customers go beyond the capabilities of Google Maps to obtain more granular location information from their SPOT satellite GPS devices.

Maypx adds a highly valuable layer of functionality that provides a full search management, control system and tracking interface that ties into any country's local maps, aerial imagery and even building plans. As a result, the technology provides users with detail about local terrain conditions as well as landmarks and features that typically do not appear on Google Maps.

Steve Wood, Mapyx Chairman, has observed first-hand how satellite messengers are used by the military and emergency responders. Mapyx has provided SPOT-based solutions to emergency services agencies across the UK including regional fire authorities and mountain rescue organizations.

"If you know where your assets are, you can deploy them more effectively. SPOT satellite messengers are being used to track vital operational assets so that teams can get those assets to the incident faster," said Wood. *"A paramedic can get a more accurate picture of how many minutes it will take an air ambulance to arrive, and where the nearest cardiac defibrillator is located in order to engage in a speedy response to a casualty to increase the odds of saving a life."*

A LIFELINE IN REMOTE REGIONS

Castilla La Mancha is a vast region in central Spain. With its dry and often very hot climate, forest blazes and wildfires are a fact of life for people and businesses in the region. Junta de Castilla La Mancha, the administrative authority whose responsibilities include forest and wildfire management, employs some 2,000 response personnel who are always on standby to help keep forest and wildfires at bay.

In 2015, the local administration decided that it should invest in new technology to help its team more effectively contain and extinguish fires. Moreover, the administration recognized a need to help crews communicate better in emergency situations and to enhance safety in the extremely dangerous situations they routinely face.

Junta officials started talking to wildfire solutions specialist Technosylva, provider of fire behavior analysis and management software, to learn about what options were available.

Joaquin Ramirez Cisneros, Principal Consultant at Technosylva, explained why Globalstar's SPOT Gen3 was selected to meet the Junta's requirements as an integral part of his company's Wildfire Management System—*"To keep firefighters safe, it is critical to know where exactly they are at all times."*

"The positions of the crew members need to be known in relation to the engine and equipment resources being used, and it is particularly important to know how far away they are from the heart of the fire. Providing these professional teams with the communications and support they need in the extremely dangerous situation of wildfire is an absolute must," he added.

Ramirez Cisneros points to two major benefits for firefighters: the SPOT Gen3's integrated sensors that report when the device is moving and the unit's ability to be powered via USB—and he should know. Prior to the new deployment with Junta de Castilla La Mancha, he provided mission-critical technology to fire-fighting organizations in Spain, USA, Canada, and in Chile.

Juan Bautista Garcia, Wild Fire Coordinator at GEACAM (Public Agency of Castilla La Mancha) said, *"Tracking our units with the reliability of the SPOT Gen3 fundamentally changes the way we can face operations. Not only is safety dramatically improved, providing situational awareness in real-time to all of the organization, it also helps to improve our response and tactics. The integration of the SPOT Gen3 is helping us to provide a better service accomplishing the highest standards of safety in the most efficient way."*

If a firefighter needs help urgently, with the single press of a button on SPOT, emergency services are alerted, his or her GPS coordinates will be transmitted and a rescue operation is initiated. Emergency services coordinators can precisely track each fire fighting team's location, via a user-friendly display of GPS positions in near real-time on Google Maps.

Elsewhere, the Forestry Commission in England and Scotland turned to value added reseller Global Telesat Communications when looking for a solution to help protect crews when working in remote areas. The Commission selected the SPOT Gen3 due to the unit's small size and ease-of-use as well as its long battery life and affordability. To date, the Forestry Commission has deployed more than 700 SPOT units.

"*In an emergency situation, particularly if a person is in danger of going into shock, having a device that is quick and easy to use is paramount. We wanted something small enough to fit in a pocket, yet able to provide a lifeline in critical situations*," said a spokesperson for the Forestry Commission. "*Many members of our team work in the most remote parts of the UK which are unreachable by radio and mobile phones. With SPOT Gen3, they have a satellite-based device that brings peace of mind.*"

HELPING NGOS PROVIDE RELIEF WHILE SAFEGUARDING STAFF

Relief organizations have also been deploying SPOT devices to help improve operational efficiency and to safeguard crews. Since 2015, the Lebanese Red Cross has been using SPOT Gen3s to track the location of its volunteers and search and rescue teams as they respond to critical emergencies including in areas with little or no GSM mobile signal. In such situations, staff and volunteers can simply press an SOS button to send their coordinates and request potentially life-saving help over the Globalstar satellite network.

Other NGOs have also been using SPOT to help them deliver aid more effectively. Disaster Tech Lab (DTL) is a volunteer-based organization that uses WiFi to reconnect disconnected communities in disaster zones across the globe. Established in 2010 following the Haiti earthquake, the organization now has over 175 volunteers working across 11 countries.

2016 was a particularly busy year for DTL. When Italy was hit by a major earthquake in August, a DTL team was rapidly dispatched to the scene to help reconnect communities and enable first responders to more effectively deliver critical support. DTL provided Globalstar satellite communications devices to the Italian Red Cross as well as to civil protection authorities and the local mayor's office.

Also in 2016, DTL came to the rescue of communities, NGOs, and local authorities across the east coast of Ecuador after that area was devastated by an earthquake and multiple after-shocks. In particular, DTL equipped Israeli organization Israaid, which delivered medical support to the injured with much appreciated SATCOM.

Since 2015, however, DTL has been facing its biggest challenge ever, namely providing critical communications support to NGOs as they strive to deliver aid and relief to many thousands of displaced people in today's migrant and refugee cities in the Middle East and Europe.

DTL began providing support as refugees began to arrive on dangerously over-crowded boats on the shores of the Greek island of Lesbos in September 2015. "*We arrived with an initial plan to provide Internet access and communications to several sites for the refugees as well as for the other NGOs working there*," explained Evert Bopp, Founder of Disaster Tech Lab. Prior to their arrival, the region where the major camps were set up had virtually no infrastructure, no electricity and no telecommunications capability.

"*Globalstar's satellite phones, hotspots and SPOT tracking devices have proven invaluable. They have enabled first responders and NGOs to do their jobs more effectively and they have helped administrators rebuild communities. And, at the same time, they have helped us ensure that our own crews stay safe*," Bopp said.

At the end of 2016, Disaster Tech Lab was recognized for their remarkable humanitarian achievements by the Society of Satellite Professionals International (SSPI) with a Better Satellite World Award.

Military and defense staff, resource management authorities, first responders and all organizations that provide emergency support and relief need to know that they have reliable tools that will enable them to communicate and call for help, whenever and wherever. They can be assured that our ever-evolving family of SPOT devices will be standing by, 24/7, to put the power and reach of a worldwide satellite system directly into their pockets.

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Gavan Murphy, Director of Marketing, EMEA at Globalstar based in Globalstar's European HQ in Dublin, is responsible for the development and implementation of Globalstar's marketing strategy across the European, Middle Eastern and African regions. He spearheads the marketing of Globalstar's consumer products, including the SPOT tracking solutions portfolio, as well as the B2B marketing of voice and data solutions for a range of vertical sectors including maritime, energy, safety and security, commercial fishing and shipping, construction and heavy industry as well as the burgeoning M2M sector. Prior to joining Globalstar in 2008, Gavan worked with leading global mobile provider Vodafone as Channel Development and Category Manager.

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33RD SPACE SYMPOSIUM

MAXIMIZING SATELLITE NETWORK UPTIME IN WINTER, SNOW, ICE AND ALPINE CONDITIONS

By Dan Freyer, Founder, AdWavez Marketing

To maximize satellite network quality and uptime and optimize costs, satellite Earth stations in regions prone to snow need de-icing systems to protect their antennas from the accumulation of snow and ice on the antenna.

In some locations, an antenna de-icing system is a "must-have" in order to prevent significant losses in signal and increases in network cost due to ice and snow, especially when using Ku-, X-, and Ka-band. The most effective and cost-efficient solution for larger, fixed-site antennas, such as Satellite Enterprise Terminals (SET), and gateways is to employ hot air de-icing.

This article discusses improvements under development that promise to bring Earth station operators new gains in network control, operational and energy efficiency.

WHY PREVENT SNOW AND ICE?

On top of the large atmospheric and rain fade effects, especially at Ku-, X-and Ka-band frequencies used by the Wideband Global Satellite (WGS) system, the accumulation of snow, particularly wet snow, ice, or freezing rain on satellite Earth station antenna reflectors and feeds, can cause significant signal loss effects. These include:

- *Attenuating the satellite signal*
- *Increasing the system noise temperature of the antenna*
- *Reducing antenna efficiency, gain, and focus, due to distortion of the antenna caused by uneven surface temperatures. Together these effects (reducing antenna gain and increasing noise temperature) reduce the G/T Figure of Merit performance, which is critical for closing satellite links.*
- *Rain and Ice also cause de-polarization depending on particles and raindrop shapes, attenuating the signal, especially if present in the feed aperture.*
- *The moisture composition of snow can vary, from dry snow to wet snow, sleet, to a mixture of snow and freezing rain.*

Freezing rain

Freezing rain droplets can turn into ice on impact with the ground or an antenna reflector. The accumulation on the bottom half of a reflector of ice formed from freezing rain can also de-focus the reflector temporarily. For example, NASA Researchers have observed in a test of Ka-band terminals that "*accumulation of snow on the parabolic*

reflector of an antenna or the formation of a glaze layer during freezing rain events can significantly degrade the received signal."

Dry snow

Although dry snowfall minimally contributes *(i.e.*, under 1 dB) to atmospheric losses (unlike rain), in a typical Fixed Satellite Services (FSS) link, the effect of snow on an antenna can significantly degrade the signal. Accumulation of snow on the bottom half of an antenna reflector can cause an uneven temperature distribution across the reflector surface, and therefore temporarily distort the parabolic geometry and disturb the focus of the antenna. The effects can be quite large in the higher frequencies, such as Ka-band, used by the Wideband Global Satellite (WGS) system, as well as X-, and Ku-bands, because tight surface tolerances are required for narrow beam widths at higher frequencies.

As an example, one research study showed that, due to the accumulation of snow in the bottom of an antenna reflector (2.4 meter and 1.2 meter reflectors in this case), uneven surface temperatures caused reflector de-focusing, creating signal losses that were as high as 6 dB at 20 GHz Ka-band. This is illustrated in ***Figure 1***, where the blue line in the top panel shows a 6 dB reduction in received signal power after dry snow accumulated on an antenna and distorted its focal point and efficiency, and reducing the gain. The red line shows the signal gain during the same period, through a co-located antenna that is shielded from the elements, and experiences no signal degradation.

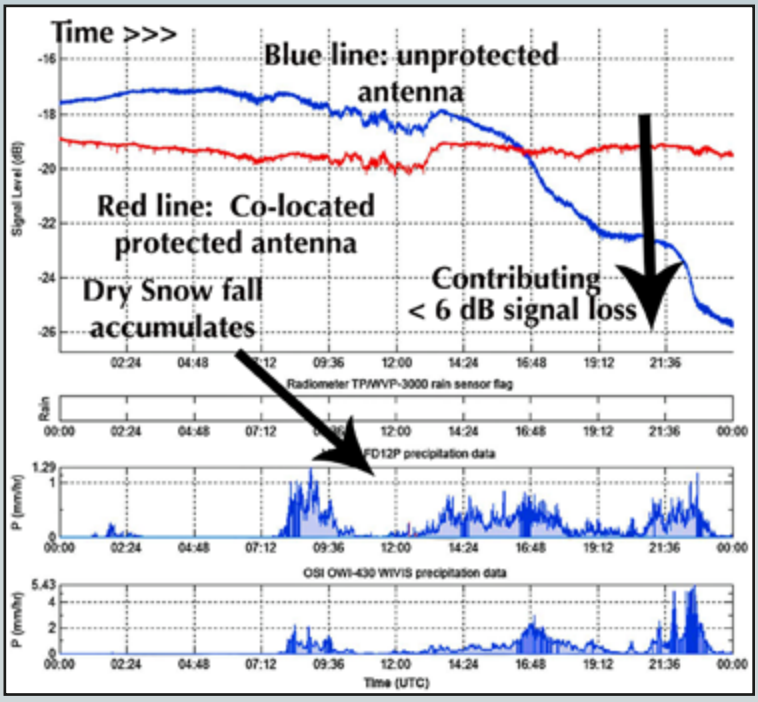

Figure 1. Courtesy of American Geophysical Union: Dry Snow Effect on Ka-Band Antenna (Black Text & Arrow Annotations Added for clarity).

Such a large decrease in signal power can create a complete network outage, if the satellite link has not been engineered with the "overhead" (or link margin) to withstand such a loss —or engineered to prevent its occurrence by using de-icing system. Consider how a rain immediately after the dry snow event could suddenly add additional atmospheric rain losses from 1-6 dB as the atmospheric/sky conditions change.

Wet snow

Wet snow has a similar effect as water in attenuating satellite signals. The influence of wet snow, due to its high liquid-water content, possesses substantial energy absorption of both cm and mm wavelength signals. Accumulation of wet snow can cause significant attenuation of the signal while simultaneously increasing the system noise.

Figure 2, (*Courtesy American Geophysical Union, see references*) also taken from research performed at Ka-Band by the Communications Research Center Canada (CRC) shows an example of an event of wet snow accumulating on an antenna. The blue line on the top panel shows a sudden drop in the received signal by about 8 dB attributed to wet snow accumulating on a test satellite antenna. The red line represents a co-located antenna protected from snow accumulation during the same time.

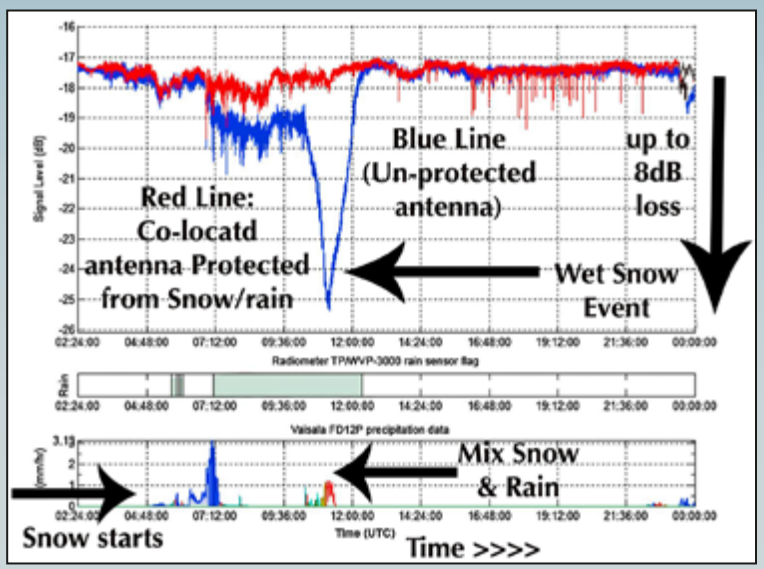

Figure 2. Wet Snow Event -8 dB Signal Loss: Courtesy of American Geophysical Union. (Annotations added in Black for clarity).

Wet snow also more easily sticks to parabolic reflectors and antenna feeds. Researchers have observed that accumulation of snow on the parabolic reflector of an antenna or the formation of a glaze layer during freezing rain events can significantly degrade the received signal (measured in 20 GHz range).

Antenna wetting

Water on the main reflector, and even more critically on the feed aperture, is another potential source of loss at 20 and 30 GHz. Rain on a reflector can create a distorted reflector surface that reduces the antenna gain by several dB in the worst case. Water on the feed aperture distorts the electric field's distribution of the feed therefore creating a high perturbation on the feed standing wave ratio (SWR). One laboratory test measured and calculated the antenna attenuation due to surface wetting can reach 10 dB at Ka-band.

ANTI-ICING VS. PREVENTION AND DE-ICING

Due to the growing demand for SATCOM in zones where snow and ice accumulate, demand has also increased for antenna de-icing sub-systems from companies such as Walton De-Ice, which leads the market as a supplier of snow and ice protection subsystems to Earth station antenna manufacturers and Earth stations.

Walton De-Ice systems are used in commercial and military satellite Earth stations around the globe for C-, Ku-, X-band, and Ka-band transmissions, including such networks as the WGS (Wideband Global Satellite), both through legacy Satellite Enterprise Terminal (SET) and Modernized Earth Terminals (MET) type facilities and gateways for telecommunications. The company's systems help the DoD's state-of-the-art SATCOMs leverage the increased throughput of the Wideband Global (WGS) satellite constellation, helping to meet the military's demand for data, voice and video around the globe as part of the military's communications backbone.

The Walton Hot Air De-ice system is uniquely designed to prevent snow and ice from accumulating on an Earth station antenna. The company's patented invention uses a plenum enclosed on the rear of the antenna. Heaters (gas or electric) located on the antenna structure heat and circulate air inside the plenum, which in turn rapidly and uniformly heats the reflector surface to remove or prevent ice and/or snow from accumulating. This is shown in *Figure 3*.

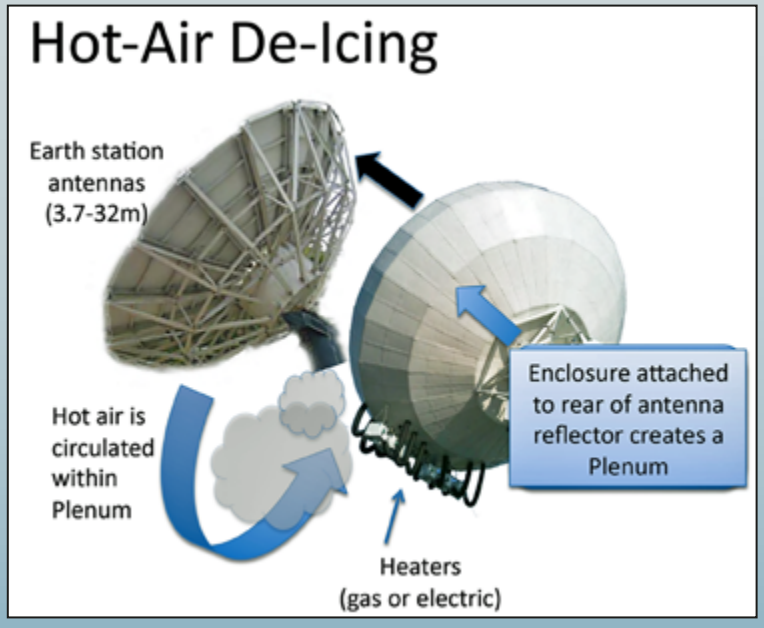

Figure 3. Hot Air De-Icing (Courtesy Walton Enterprises, Inc.)

In order to provide maximum flexibility, Walton offers electric, natural gas, and liquid propane gas heaters so a customer can make their choice, based on the cost and availability of the fuel source at their location. Depending on the Earth station site, gas heaters may offer economical operation advantages, or the low maintenance Stainless Steel Electric Heaters may be advantageous. The Plenum enclosure also hides the unsightly metal support structure and additionally prevents birds from nesting in the back structure of the antenna.

Anti-icing techniques

Most antennas have reflector panels that are mounted onto truss supports that are then tied together. Anti-icing solutions that only heat the individual reflector panels cause distortion losses by creating temperature differentials between the reflector panels and the truss supports. Metals expand at different rates when heated. Antenna panel thickness and size varies.

This size difference can contribute to the uneven heating of a reflector's metal panels with pad-based anti-icing solutions, as they tend to leave a checkerboard footprint that creates cold and warm strips on the reflector surface. Non-uniform heat applied to the antenna structure can cause de-focusing and reflector degradation. If not well designed, these kinds of products can produce high antenna gain losses (up to 6dB in Ka-band).

Unlike electric pad or heat tape anti-ice, the Walton Hot Air de-ice system heats the entire antenna reflector and back structure and uniformly distributes the heat. This minimizes the chances of reflector distortion (which can cause signal problems) caused by thermal expansion and contraction. Results show transmit and receive gain degradations at Ka-band were substantially reduced by this hot air method, down to the 0.6 to 0.75dB range for 9.2 meter to 13.2 meter Ka-band antennas, for example. That is a dramatic performance improvement when compared to the previously mentioned 6dB loss figure using other anti-icing methods.

Figure 4 shows an example of thermal measurements on an actual antenna using a Walton De-Ice plenum system. In this example, infrared photo measurements of heat across a large antenna reveals the temperature variation before, and after, the Walton De-Ice system has been activated.

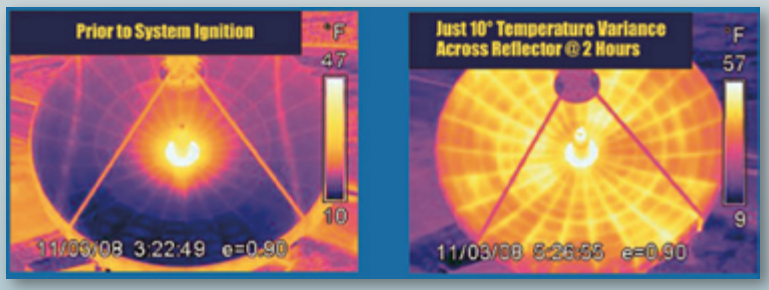

Figure 4. Image is courtesy of Walton De-Ice.

Feed and sub-reflector protection

As noted earlier, the amount of water in reflector antennas (reflector and feed) can cause additional signal loss (up to 4 to 5dB) on top of the expected propagation attenuation due to rain at Ka-band, depending on the antenna size, type of antenna, and elevation angle. For both antenna sub-reflector and feed de-icing, Walton systems re-use the heated air from the Plenum, which is ducted to the feed horn and sub-reflector, using a blower. The same systems also perform rain diversion to clear the feed horn window of moisture, which can significantly degrade Ka-band, X-band, and Ku-band signals.

HEATING EFFICIENCIES

A pad-based anti-icing system must maintain heating, even if it has a temperature threshold that turns the system on automatically when a cold weather threshold is present. Thus, a heat-pad-based anti-icing solution consumes far more energy dollars than, for example, a gas-heated, Walton Plenum solution, which detects the presence of moisture and temperature, and responds by rapidly and uniformly heating the antenna, thereby conserving power.

Automatic temperature sensing and integrated control of the Walton De-Ice Plenum ensures that sufficient heat is uniformly applied to the reflector surface to minimize the thermal effects on antenna gain. The design itself minimizes thermal expansion of an antenna structure. Temperature distribution is controlled with the use of circulation fans and heat distribution systems within the plenum.

NEW TEMPERATURE CONTROL / MONITORING SYSTEM (TCM)

The newest TCM developments from Walton De-Ice will provide a way to passively monitor antenna surface temperatures, and a method to actively control the antenna surface temperature.

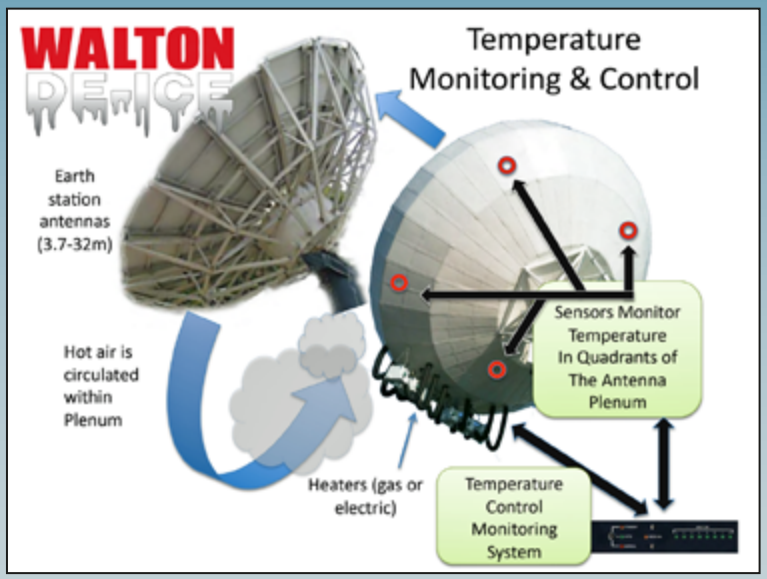

Figure 5. Hot Air De-Icing with Temperature Control/Monitoring

Four remote digital temperature sensors are mounted on top, bottom, and side quadrants inside the main reflector Plenum. These sensors are accurate to within + 0.5 degrees Celsius. The digital plenum temperate information is returned to a unit mounted on the Power Distribution Panel. Readings are scaled, then forwarded via a serial link to a 1RU rack-mount display panel. This gives users a rolling digital display of the operating temperature of each quadrant of the main antenna reflector so operators can confirm the proper operation of the De-Icing system.

In addition, the new TCM systems will be configurable to replace the fixed mechanical thermal switches previously used to activate and de-activate the de-icing heaters. An on-board relay opens and closes on cue from the digital temperature sensors inside the plenum, firing the heaters as needed. Heat from all heaters in the hot-air De-Ice system will activate and deactivate at the same time. The heater fan/blower motor will operate as long as there is a call for De-Icing. This adds new operator flexibility that has not been previously available when fixed thermal switches are used. With the latest version, a user will be able to easily adjust the operating temperature of their De-Icing system. This assures reliable melt-off, while potentially reducing operating costs. Manual override for testing and special operating conditions remain available.

As discussed, higher frequency antennas require tight surface tolerances. Temperature imbalance during non-de-icing conditions can introduce uneven expansion and contraction of the main reflector. This may occur when sunshine is on a portion of the reflector and shadows are on another portion. To help combat asymmetry, and optimize the reflector's gain and accuracy, the new TCM system will be configurable to assist in maintaining an even surface temperature. The unit monitors the temperatures of the reflector plenum quadrants. An operator/user is able to set the desired allowable temperature difference ("span") between all quadrants. When that number is exceeded, a relay is closed, activating circulation fans inside the antenna plenum, which disperse "hot spots" and levels the antenna reflector surface temperature differences. A rack-mount unit also offers a monitor and control interface for remote system supervision. Temperatures and relay activities can be monitored remotely.

With these new developments in Temperature Control and Monitoring, Earth station operators do not have to guess that their de-icing system is functioning properly because they can see that all the antenna quadrants are heated. Users can leverage a digital temperature display of antenna surface in real-time. This toll allows users to control reliable melt-off while potentially reducing operating costs. Saving fuel energy and bandwidth can even save lives in a conflict zone. Antenna De-Icing with new Temperature Control & Monitoring capabilities promise benefits to Earth station and SATCOM services. They can offer cost-savings opportunities to organizations running satellite Earth stations, as well as enhanced link margins and network uptime.

Hot Air De-Icing systems can also protect the new generation of Ka-band satellite networks from large signal losses (*e.g.*, 8 dB) and potential outages on critical links. They can also enable network designers to avoid budgeting for such large power losses in the satellite link and network design. The resulting efficiency gains can translate into both capacity increases and cost-saving benefits for military SATCOM networks.

de-ice.com/

Dan Freyer is founder of AdWavez Marketing (www.AdWavez.com), a marketing communications agency uniquely focused on, and experienced in, the satellite industry. Clients benefit from his 20+ years of industry experience helping top spacecraft manufacturers, satellite operators, service providers, equipment manufacturers and integrators, and associations build their markets around the world. He can be reached at ***dan@adwavez.com****.*

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3 Special Effects: Antenna Wetting, Short Distance Diversity and Depolarization Roberto J. Acosta , NASA Glenn Research Center, Cleveland, Ohio 44135, Phone: 216-433-6640, Fax: 216-433-6371. E-mail: Roberto.J.Acosta@grc.nasa.gov

THE IMPORTANCE OF MILITARY AND GOVERNMENT SATELLITE CONNECTIONS

By Robert Stanton, Director of Technology, Omnetics Connector Corporation

Military and government programs are heavily involved in greatly expanding our work in space research, exploration, orbit management and satellite coordination systems.

Many of these mission critical satellites must be rugged and perform for long periods of time in extreme environments. To meet these demands, highly focused space-qualified electronic modules, hardware and interconnecting systems have been developed by the company.

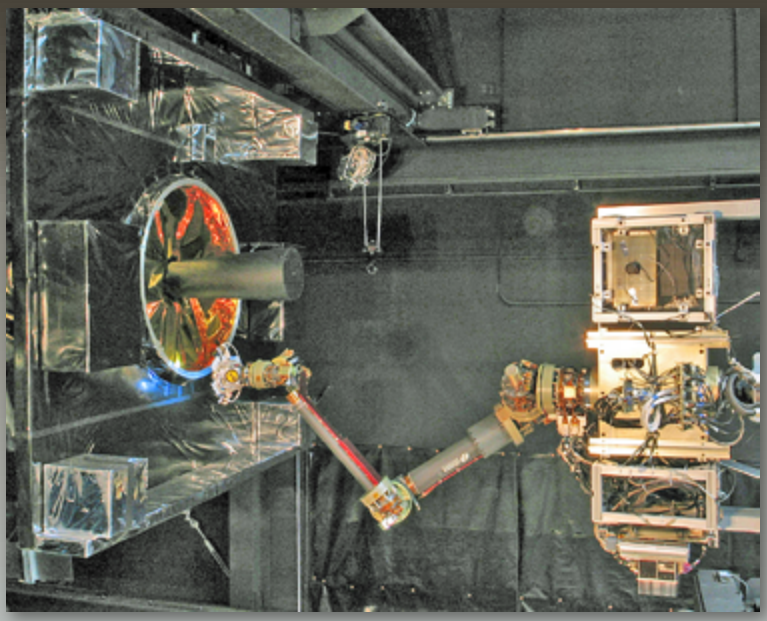
In addition to their ruggedness, these new modules offer extensive technology upgrades for key military and government level orbital craft. Military and government research centers have teams working together and continue heavy investing in the newest of technical capabilities beyond our current level of expertise.

For example, new micro-chip circuits have helped drive improved and expanded surveillance and geo-mapping capability using triple-layer CMOS imaging designs that supply full color imaging at low cost and low power. They are now providing high resolution photos while passing over key points on Earth at more than 17,000 miles an hour.

To launch new orbital devices, one must also consider the circuit details and signal technology needed. Beyond launch RF signal management, modulated digital formats and signal aiming requires aiming and positioning beams to help maintain contact with each satellite. This helps coordinate the relative position of each satellite and working with satellite cluster management.

New programs are developing docking and repair satellites to upgrade and sustain existing orbital devices while still in space. These advanced programs add challenges to develop and sustain reserve power sources, to articulate robotic satellite collectors and provide satellite to satellite continuous communication and position control. This is today's era of design and implementation of multiple, mixed module space electronic colonization, management and control. These military and government satellites require high reliability while exposure to external environments, ruggedized longevity, and continuous performance with the minimum physical size, lowest weight and highest signal processing capability, storage and transmission possible.

The wiring maze aboard the ISS Space Lab. Photo is courtesy of NASA.



The NASA Naval Proximity tester. Photo is courtesy of NASA.

Electronic connectors and cable systems are a serious part of that program and careful selection applied with attention to these criteria. Connectors and cable perform a large role in meeting the demands of the overall system.

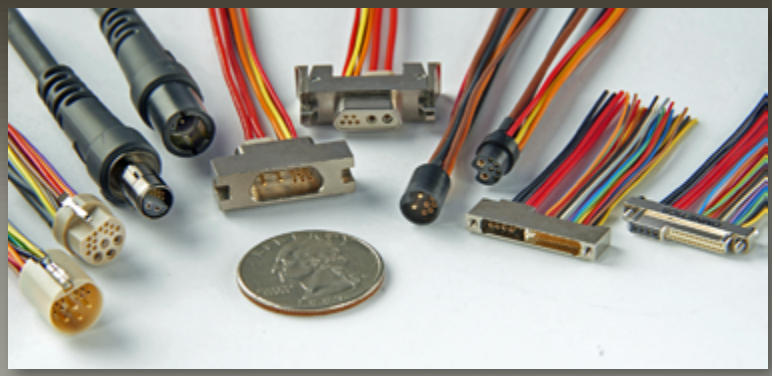
At times, a combination of electrical and mechanical devices must be working together. The design engineer should pay attention to both disciplines to insure performance. Robotic arms, satellite launchers, release modules, and camera articulators operate in simultaneous mode.

One example shown in the photo is the Navy Labs and NASA proximity test system. It is used to help check out satellites while still on orbit. Connectors must handle higher amperage to operate the actuators and driver motors but also include small signal interfaces. In this case, one option is to use two separate cable and connector interconnections. Unfortunately that adds weight and consumes room for both.

A better option is for the engineer to design a combination cable using what is called mixed-signal design. When the amperage needed for robotic motors is specified and the type of electrical signals are specified, a connection engineer can draw from proven sub-components and design an application-specific cable and connector.

This is often accomplished using a solid modeling design software that includes an inventory of each of the key connector elements using space qualified materials. The concept design model would include shape, dimensions, alignment keying, and even shielding if it is required. This model is then sent to the satellite design team for confirmation and or adjustment. Improvements include the size and weight reduction, faster design cycle and costs are significantly reduced using this method.

Finally, the design team has high assurance that the final interconnection system comes from previously tested and used components. Specialty cable is handled similarly, using both electrical and mechanical models to layout a cable that meets the applications needs. This would include cable diameter, jacket ruggedness, braided shielding if needed, and then include a wiring map of protecting each signal for noise, or crosstalk.



Omnetics' mixed signal connectors.

The power lines can still be inside the cable but isolated from the signal section. If the cable is going to handle very high speed digital signals, the cable design changes somewhat. Twisted differential pair wiring is used with separate drain wires for each high speed section.

With a specified impedance to match the drive circuits, a micro or nano connector can serve over 7 Gigabits per second. Many space surveillance systems need this capability. When a high speed combination connector and cable system is assembled it can also be tested for all the basic functions before being sent to the space lab.

Final electrical tests include most basics such as impedance, insertion loss vs frequency, signal reflections, noise and jitter. More and more, critical systems also request eye-diagrams testing to help predict system performance and signal capacity.

Eye diagrams also can be simulated using spice-models based upon the elements in the cable. Experienced cable and connector design suppliers retain correlations of their simulations to save time and cost and assure performance quickly.

Initial cable and connector selection begins with a review of space qualified materials with specifications and should meet the NASA mission critical screening specification EEE-INST-002. One should include, depending on standard designs that have been tested and used in military applications, such as MIL-DTL- 83513 for micro-d connectors and MIL-DTL-32139 for Nano-d connectors.

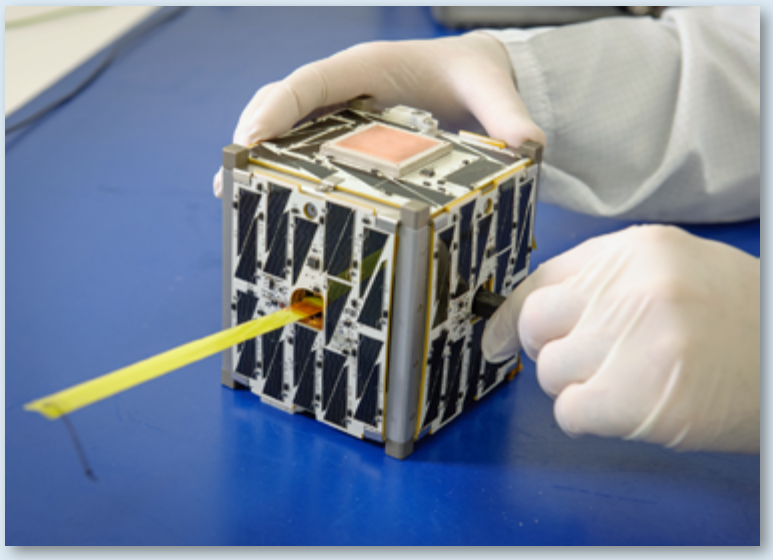


Image is courtesy of NASA.

COTs and standard connectors are a popular buzz these days by some to get connections rapidly and a lower costs. This can be a great solution, but only if the supplier has tested the materials, used low outgassing polymers and their product matches with the reliability of those well-defined military products.

Omnetics ratchet locking circular connectors.

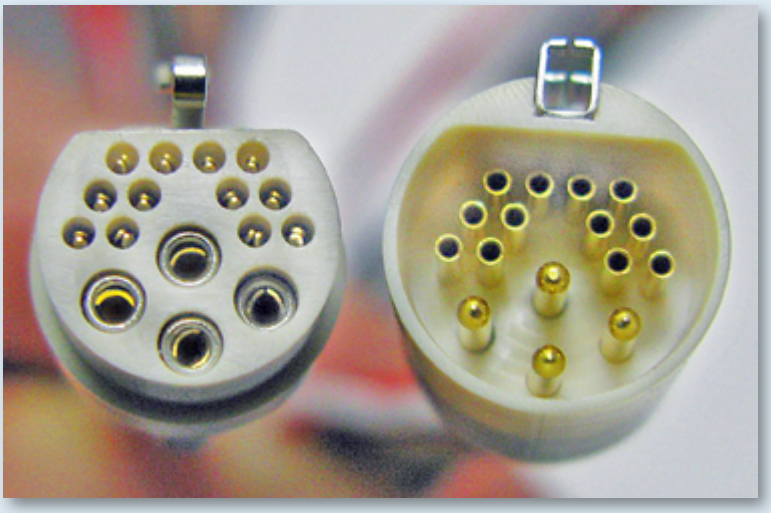
One example in selecting a connector to last through the rigors of high shock and vibration during launch is to look at the pin and socket design system used within the connectors chosen. Selecting a pin made of tempered Beryllium Copper that is plated with nickel and gold will perform continuously without what is called fretting loss. (That is small movement in and out of the socket that rubs away the gold contact and leaves a highly resistive nickel interface. Better connectors can exceed 2,000 mates and de-mates before wear begins to show.) Also, the connectors should interface smoothly and firmly, and have a strong key alignment control feature.

Small circular connectors are frequently used in the smaller satellites during assembly and testing. Somewhat larger connectors are more often used for routing from unit to unit or to the main power source. Larger circular connectors can also be the work horse for system to system communications within a satellite, however as voltage levels are decreasing as well as high current demand, more circular connectors are also being downsized.

Mil-DTL 38999 and Micro-circular connectors can serve much of today's new satellite systems. When necessary, this size connector can also contain 2 to 4 large pins for heaviest current loads selected for amperage ratings at space elevations. This method also helps in maintaining smaller diameter wiring and connector bulk with micro-sized pin and socket interconnects for signal processing.

Ratcheting micro-connectors are also used in robotics for highly fixable interconnects that are assembled and de-assembled quickly. The threaded couplings have metal alignment keys and insulators for quick alignment and mating, even while wearing gloves. The feel of the latching process, assures the installer that connections are positive and tightly mated. Nickel plated aluminum shells assist blind mating with first-touch alignment.

Connector contacts in space quality connectors also use military standard 83513 pin and sockets and are made of BeCu plated with mil quality nickel and gold for extended use. Metal shells and EMI shielding can be specified as well unique plating needs to prevent corrosion etc.



Omnetics Micro Circular Power Plus.

Coax cabling and connectors for high speed analog systems plus for broadcast transmission is another area requiring exact attention to quality of signal management as well as reliability. Designers must focus as well on what is called, the signal launch point from the transmission board to the back end of the connector and on through the connector into the cable. This is a complete study in itself and can be covered in another report.

In conclusion; the satellite industry is expands globally, seeks to travel further and also to combine multiple satellites into a cohesive webs. We see nations pulling together and specifying space quality connectors for their satellites.

One good example is the SARah system that consists of three satellites and two ground stations. The space segment consists of two satellites equipped with the reflector technology from OHB, and a third satellite, equipped with Airbus Defence and Space's proven phased-array technology.

The term 'phased-array' is used to describe phase-controlled antennas made up of numerous individual transmitter/receiver modules which can be interconnected, bundled and variably controlled. This enables direction and range of view to be adjusted without needing to move the antennas mechanically, thus providing the user with rapid image sequencing, variable image sizes and 'blur-free' recordings.

A key to phased array technologies, is having highest quality, multiple pin connectors for the very many output lines required to rapidly download the data generated by the antenna array system.

Satellite designers can benefit greatly from direct interface communications with their connector design source. Many have check lists made specifically for space quality connectors. There are numerous challenges that include simultaneous combinations of size reduction, lower weight, increased ruggedness, custom cable routing, and management of power in close proximity to high speed signal management.

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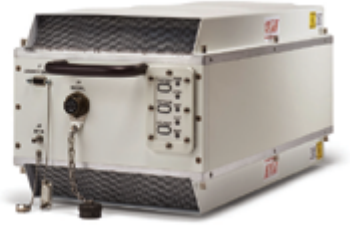

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