WHITE PAPER

INTELSAT General

Realizing Resilient Tactical Networks with Maximum Government Control on High-throughput Satellites

Wide-beam connectivity is an essential aspect of military satellite communications and High Throughput Satellite (HTS) technology is proving to be ideally suited for many Government applications. While most satellite operators offer closed HTS architectures that are vendor-locked with very little control offered to users, the Intelsat Epic Next Generation (Epic) HTS architecture is enterprise-grade, open architecture and vendor-agnostic. Intelsat Epic allows Government and military access to bandwidth-efficient, higher data throughputs on a global-scale via a wide variety of user-chosen waveforms, modems and antennas. Intelsat is proud to present the next generation of satellite communications that features higher data throughput rates and security while offering cost-efficiencies across the board.

Introduction

High Throughput Satellites (HTS) have been the center of attention for the past five years. It is important to note that most of these systems have been purpose-built solutions to service homogeneous sets of users via closed architectures. Systems such as ViaSat Exede, Inmarsat Global Express, Hughes Jupiter, and Eutelsat KA-SAT require new investments in proprietary modem technologies and service architectures. These closed systems offer star-only connectivity and keep quality of service control with the service provider, not the end users. These closed HTS systems are effectively commodity-based modems for the satellite world. If connectivity to the Internet is all one needs, then these managed services solutions provide adequate capabilities at a fair price in their limited coverage areas.

For a variety of reasons, most government SATCOM networks cannot migrate to a closed architecture. Unmanned ISR platforms require flight certified hardware and continuous positive control; making a switch to proprietary hardware cost-prohibitive. Upgrades to naval ships are also costly and require 3-4 years of planning and execution. Ever-evolving cyber requirements including encryption, security, and information assurance are difficult to incorporate into managed services solutions. Interoperability between the various military branches, allied, and coalition forces continues to be a challenge. Finally, most military and government users require operational coverage in remote and austere regions such as deserts, jungles, and oceans—well outside of population centers for which these closed architectures are optimized.

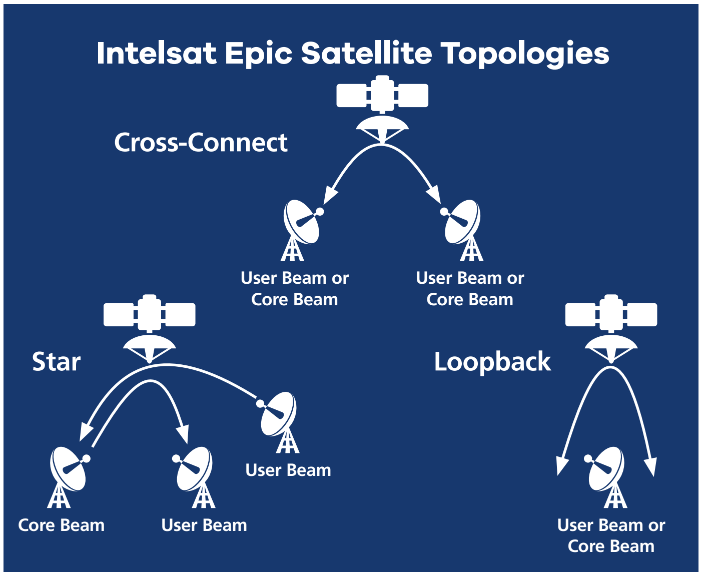
With the disconnects between these closed HTS solutions and the challenges faced by the Government, it is no wonder that the Government is slow to adopt HTS services and instead is choosing to continue down the traditional wide-beam acquisitions. This can be seen in the U.S. Air Force Pathfinder and Pilot programs as well as DISA's CTC and CSS task orders.

However, open architecture HTS systems are operational today and can be leveraged immediately by Government users. Intelsat Epic, one such open architecture, supports a wide range of communication topologies, terminal and modem hardware, and connectivity to support the diversity of typical Government requirements. Users have control over their network design and can leverage existing ground terminals and infrastructure, without modification, to realize significant gains in throughput, efficiencies and capabilities.

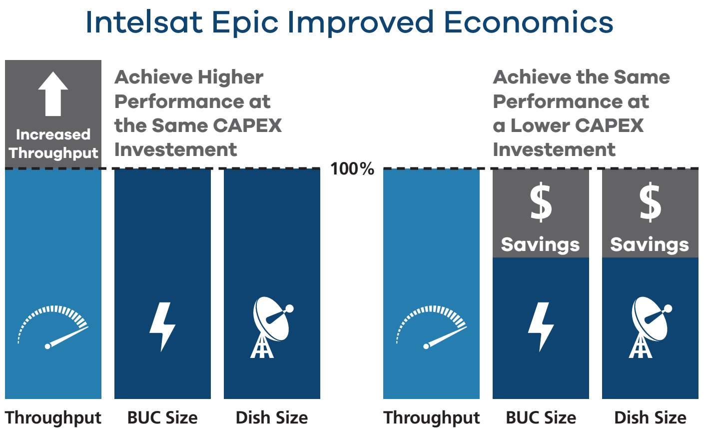
Intelsat Epic Next Generation Architecture

Many potential users have been misled into believing that HTS systems work only in the Ka-band. This is inaccurate as the significant benefits of HTS can be applied to any frequency band. The Intelsat Epic platform is frequency-agnostic in its HTS design and applies high frequency reuse in both C- and Ku-band to deliver more throughput per unit of spectrum. In addition, C- and Ku-band are less susceptible to rain fade, a critical consideration for many government applications. Both implementations of Epic are available, today, on a global scale and complement Intelsat's worldwide network of wide-beam satellites and global IntelsatOne terrestrial network.

Epic is engineered for backwards compatibility, allowing government organizations to realize high-throughput performance utilizing their existing hardware and network infrastructure. This increased efficiency without loss of control means that organizations can offer their end users customized, differentiated solutions by defining network topology, hardware and service characteristics appropriate to that user. This architecture permits any beam to be connected to any other beam allowing for star, mesh, and loopback network topologies.



Intelsat Epic meets the demand for broadband connectivity around the globe, enabling the delivery of a greater variety of solutions, with improved economics, to more customers. An Epic high-performance satellite platform provides government and military users with up to 6 times the bandwidth equivalent of a conventional commercial satellite or a Wideband Global SATCOM (WGS) satellite. By leveraging a mix of wide, steerable, and high-performance spot beams for thin and thick route traffic, as well as by leveraging existing terminal infrastructures, Epic offers outstanding performance, flexibility and security, providing the best value for government connectivity solutions.



Intelsat Epic's enhanced digital payload enables significant flexibility to the end users' overall experience. The Epic digital payload, developed by Boeing, and a next generation version of the payload on the initial WGS system, is one of the most advanced digital payloads in the satellite industry today. The onboard digital payload allows for connectivity in fine bandwidth increments and from any beam to any beam. For customers integrating high-throughput capacity into their operations, uplinks and downlinks can be connected regardless of location within the footprint and across frequency bands. This enables the military to leverage deployed antenna/modem/teleport infrastructure; in both Ku- and C-band. This ability to use current ground equipment leads to substantial cost savings for the customer, while simultaneously enabling them to benefit from the latest advances in secure-commanding and telemetry, protected communications and interference-mitigation technologies.

In June 2016, Intelsat and Boeing successfully tested the U.S. Air Force's Protected Tactical Waveform (PTW) on an Intelsat Epic satellite, proving that this PTW is compatible with commercial satellites. The PTW implements unique software inside the modem and protects communications from being jammed. The PTW waveform was transmitted through the Intelsat Epic digital payload and the performance quality of the high-data throughput was measured. The testing covered:

- **Digital payload performance, built-in features, and measurement data to support monitoring and system validation of the transmission levels for various traffic loading scenarios.**
- **Modulation schemes ranging from QPSK to 64APSK utilized commercially in Intelsat services and applications.**
- **Compatibility between the digital payload and Boeing's PTW used to support anti-jamming capabilities for government applications.**

Boeing developed the digital payload initially for use in the U.S. Department of Defense WGS satellites and also manufactured the Intelsat Epic satellites. The digital payload technology will be included exclusively on the Intelsat Epic satellite platform for several years.

When the DoD-CIO's office issued the policy requiring that all DoD SATCOM utilize satellite Telemetry and Command link encryption on their satellites in 2012, Intelsat heeded the request. Intelsat proactively changed the design of all its future satellites to incorporate the National Security Agency (NSA)-approved command encryption, as required in U.S. CNSSP-12: National Information Assurance Policy for Space Systems. While all Intelsat satellites currently have uplink Command encryption as the base design, Intelsat became the first commercial operator with a fully compliant CNSSP-12 qualified asset in space with the launch of IS-35e in early 2017. IS-35e and all following satellites incorporate both Telemetry (satellite downlink) and Command (uplink) encryption. To date, no other commercial operator complies with CNSSP-12. This demonstrates Intelsat's willingness to lean forward and implement Government-specific requirements in a responsive fashion.

Currently, there are 5 Intelsat Epic satellites on-orbit covering approximately 80% of the earth's landmasses and littoral waters with high throughput beams. The most recent launch of an Intelsat Epic satellite, Horizons 3e, provides coverage of Australia, the Pacific Ocean, and McMurdo Station in Antarctica. These areas represent the majority of the ground mobile, fixed site, air traffic, and naval operating lanes.

As Intelsat continues to replenish and grow its fleet, new capabilities and capacities will be added to the Intelsat Epic constellation. Epic is the first step toward software-defined payloads with fully-configurable and steerable coverages. The future will bring more agile power and frequency allocations, more resilient connectivity, better security, and greater coverage.

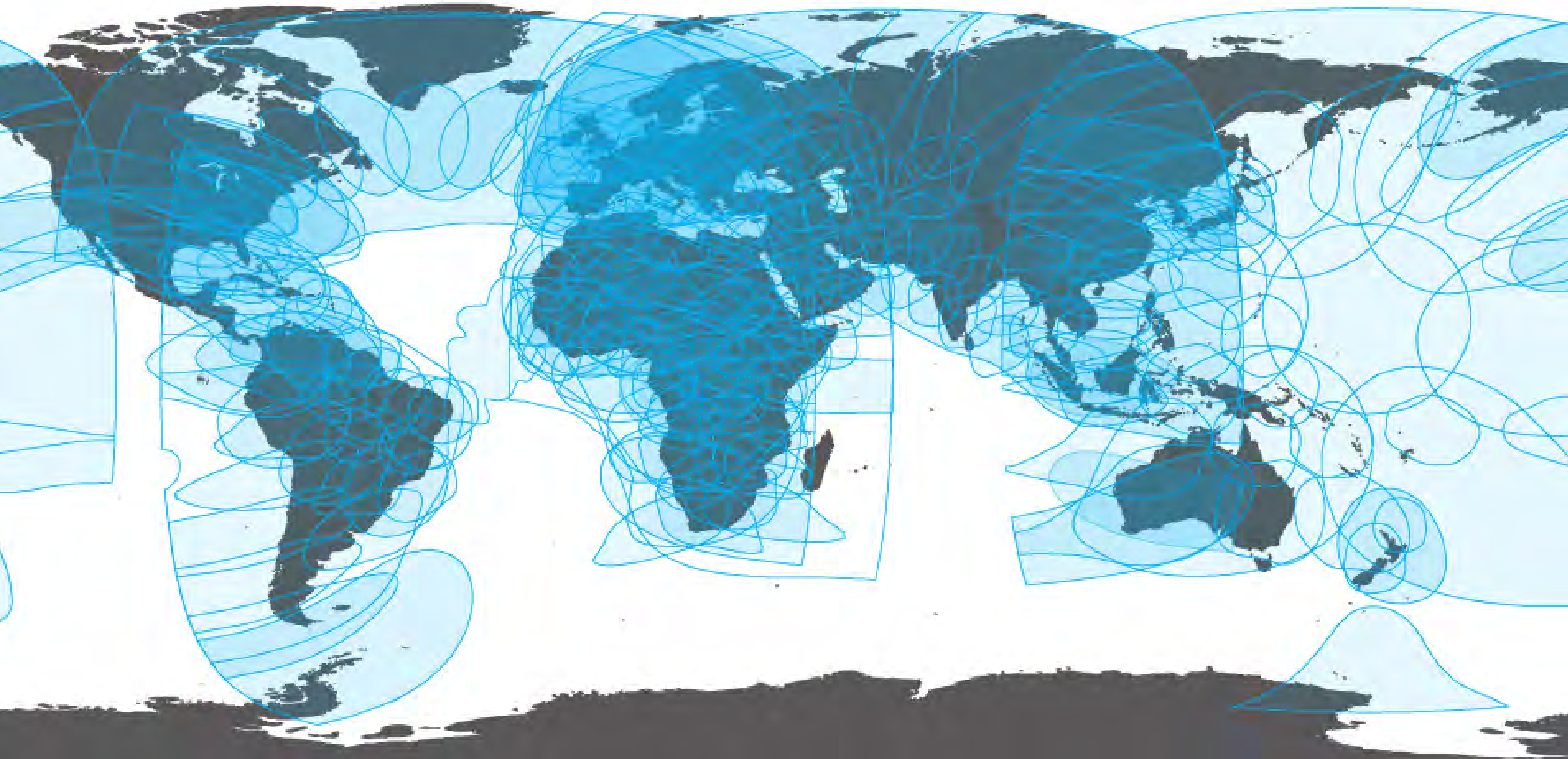
Case Study 1: Intelsat Epic brings Superior Capability to Unmanned and Manned ISR

AISR missions often use smaller, so-called disadvantaged, satellite terminals. This need is driven by size, weight and power (SWaP) requirements and other operational constraints. The high EIRP and G/T performance provided by Intelsat Epic satellites are very advantageous for these smaller terminals. The higher G/T provided by Epic-class satellites, translates into higher transmission rates from existing terminals and/or less terminal EIRP per transmitted Mbps. When Gilat Satellite Networks approached us to do some testing over Epic in support of their partnership with Diamond Aircraft on their DA42 MPP Guardian aircraft designed for homeland security applications, we were happy to help out.

In May 2016, Gilat brought their newest creation, the BlackRay 71 (BR-71) airborne terminal, with a mechanically steered 6-inch square flat panel array, to Intelsat's Mountainside Teleport near Hagerstown, Maryland. In addition to small manned aircraft, the Gilat terminal is designed for a new generation of small Class III Tactical Unmanned Aircraft Systems (TUASs), such as the RQ-21 Blackjack and Shadow M2. Class III TUASs are targeted for use in Intelligence, Surveillance, and Reconnaissance (ISR) operations and other non-military Government and commercial applications.

Data was sent from the small airborne BR-71 antenna to the Mountainside Teleport via an Intelsat Epic satellite at a rate of 3.9 Mbps with an efficiency of 0.26 bits/Hz occupying only 15.2 MHz of bandwidth at BPSK 1/3. This compares to an uplink rate of about 1.8 Mbps and efficiency of 0.09 bits/Hz achieved with a conventional wide-beam satellite occupying 20 MHz of bandwidth at BPSK 1/4 with 2x spreading. The link via HTS Epic was effectively twice the data rate and almost 3x more efficient than traditional wide-beam satellite links.

Intelsat Epic Satellite Coverage



In August 2017, General Atomics Aeronautical Systems, Inc. (GA-ASI), in collaboration with Intelsat General, flew its first test flight out of its new Flight Test and Training Center (FTTC) facility in Grand Forks, North Dakota. The GA-ASI Block 5 Predator® B/MQ-9 Remotely Piloted Aircraft (RPA) flew a round-trip of approximately 1,075 nautical miles. This was the first time an unmanned aircraft operated through multiple spot beams of a High Throughput Satellite (HTS) verifying the automatic beam switching functionality of the Predator's SATCOM terminal with the Intelsat Epic satellite. As the Predator's mission distance increases, it needs to be able to transition seamlessly from one satellite beam to another.

"These tests show that … the Intelsat Epic satellite delivers superior performance using Gilat's very small airborne antenna," said Skot Butler, President of Intelsat General. "The satellite receivers are more sensitive and can pick up a smaller and weaker signal even better than we expected."

"The outstanding test results are testimony to our successful strategy to support the growing UAS/ISR airborne market" said Moshe (Chico) Tamir, Corporate VP and President, Strategic Initiatives, at Gilat. "The transmission of full-motion HD video at a bit-rate of 3.9 Mbps using only 15.2 MHz of bandwidth, while using such small terminals, is a breakthrough, with wide-ranging implications for both military and commercial markets."

The initial demonstration was conducted at the Federal Aviation Administration (FAA) UAS test site in Blackstone, VA and attended by representatives from the U.S. DoD. This facility was opened in 2013 to support the safe and efficient integration of UAS into the National Airspace System.

Case Study 2: Intelsat Epic enables U.S. Marine Corps to take full advantage of NOTM

Developed by the Army Warfighter Information Network-Tactical Program Office (PM-WIN-T), the Network Centric Waveform (NCW) serves as a dynamic waveform that optimizes bandwidth and satellite utilization, providing efficient SATCOM capabilities for WIN-T Increment 1 at-the-halt and for WIN-T Increment 2 while at-the-halt and on-the-move. In October 2016 at Camp Lejeune, North Carolina, the U.S. Marine Corps (USMC) and the Navy's Space and Naval Warfare Systems Command (SPAWAR) conducted testing to evaluate HTS technologies to support Networking-on-the-Move (NOTM) requirements.

USMC typically deploys with two types of key SATCOM assets: the Point of Presence Vehicle Kit (POP) and the Tactical Entry Point (TEP) Modem Kit (TMK) for a 2.4-meter Small Tactical Terminal. NOTM provides access to three network enclaves, Secret Internet Protocol Router Network (SIPRnet), Non-Secure Internet Protocol (IP) Router Network (NIPRnet) and Mission Specific. NOTM incorporates Full Motion Video (FMV), Voice Over Internet Protocol (VOIP), and other data centric capabilities onto these Marine Corps tactical vehicles.

The testing had two phases, normal operations on typical wide-beam satellite (Intelsat Galaxy 3C) and enhanced operations on an Intelsat Epic HTS. Both phases utilized the General Dynamics 20-20M SATCOM-on-the-Move (SOTM) 20-inch antenna and the L-3 Linkabit MPM-1000 NCW modem in the POP and TMK units.

While operating over Galaxy 3C, information rates from the TMK to POP were limited to 1536 kbps and 256 kbps from a POP to the TMK for a nominal aggregate throughput of 1.8 Mbps. Due to the small size of the SOTM antenna aperture, the POP node had to operate at BPSK 1/2 rate and was required to spread the carrier by a factor of 12 in order to establish compliant communications. In the 9.7 MHz allocation, this severely limited the amount of bandwidth available for higher burst rates from the TMK to the POP.

While operating over the Intelsat Epic satellite, USMC users were able to achieve a total simultaneous throughput capacity of approximately 9.0 Mbps utilizing the same 9.7 MHz bandwidth allocation. Using the same, small aperture antenna, approximately five times more throughput was achieved in the same amount of bandwidth than on a traditional wide-beam satellite.

"The challenge for us is that it's not about the technologies; it's the ability to integrate. It's the ability to craft tactics, techniques and procedures, the organization of constructs by which you can do this," said Lt. Gen. Edward Cardon, Army Cyber Command (ARCYBER).

Due to the high power of Intelsat Epic satellites, the POP was not required to spread its transmitted carrier as is normally done on a wide-beam satellite. This bandwidth savings allowed burst rates of 3072 kbps between two POPs and the TMK nodes. In addition, high link margins on Intelsat Epic satellites enabled the NCW network controller to schedule direct POP-to-POP full-mesh bursts at a rate of 1024 kbps. On wide-beam satellites, hub-assisted mesh mode must typically be utilized to enable traffic routes between two, small aperture, POP nodes. Hub-assisted mesh doubles both the round trip delay and the bandwidth requirements. Transmitting two simultaneous 3072 kbps carriers was also possible using the dual internal MPM modulators at either the TMK or POP node.

SPAWAR made a point to note that the performance of the NOTM MPM NCW satellite network operating on the Intelsat Epic satellite was comparable to the performance observed while operating on a Wideband Global SATCOM (WGS) satellite in Ka-band.

Case Study 3: Intelsat Epic Enhances Widely-deployed Ground Network Technology

iDirect Evolution is widely adopted in the U.S. Government with Ground-based Fixed/Deployable networks across the DoD such as the USSOCOM C2 networks, the Army CSS-VSAT network, and the DISA Enterprise SATCOM Gateway (ESGM) initiative.

"The extreme portability of our sub-meter GATR-FLEX terminal and IGC's new high-throughput, high-performance satellite have been successfully tested to deliver command and control (C2) in addition to full-motion video capabilities," said Paul Gierow, president of Cubic|GATR.

In April 2016, IGC conducted iDirect Evolution performance testing on one of it's Intelsat Epic satellites on a number of DoD user terminals from Tampa Microwave, L-3 GCS Panther II, Harris Seeker, GATR Flex and TECOM KuStream, to measure capability and verify gains on the first Intelsat Epic satellite. IGC specifically chose test assets that reflected the combatant commands desire to field systems with lower size, weight, and power requirements (SWaP).

IGC set up a test network on the satellite utilizing 12 MHz for the forward and return links each. Leveraging the hub terminal at Intelsat's Mountainside Teleport in Hagerstown, Maryland and various remote terminals, a TDMA network was established. Testing was conducted with multiple terminals and is summarized in the table below.

To compare Intelsat Epic performance to legacy wide-beams, a baseline was set based on IGC's experience of maximum throughput capability of various well understood customer networks, adjacent satellite interference, and ITU power spectral density (PSD), and terminal performance characteristics. IGC has operated many iDirect Evolution networks for a wide variety of customers on legacy wide-beam satellites. On a typical Intelsat satellite wide-beam satellite the TECOM Ku-Stream 1500 airborne terminal could achieve 8 Mbps inbound (0.67 bits/Hz) and 1.9 Mbps (0.21 bits/Hz) outbound.

On an Intelsat Epic satellite, the TECOM terminal achieved 17.5 Mbps inbound (1.46 bits/Hz) and 9.1 Mbps (1.01 bits/Hz) outbound, yielding data rate improvements of 219% and 479% respectively. Broadband speeds to the tactical edge enable new network capabilities and applications not normally associated with traditional VSAT communications such as high definition full-motion video (HD FMV) and high data rate backhaul.

Information dominance is a key enabler in today's military operations where throughput is paramount. Government networks continuously grow in size and complexity while remote systems decrease in SWaP; these evolutionary changes are undeniable and depend on the increased capability HTS systems like Intelsat Epic brings to bear. With more platforms, missions, and services battling for bandwidth, more throughput and speed is vital.

iDirect Evolution Performance Testing on Intelsat Epic

Terminal	Intelsat Epic Data Rate				Galaxy 19 Data Rate			
	Transmit (Mbps)	Efficiency (bits/Hz)	Receive (Mbps)	Efficiency (bits/Hz)	Transmit (Mbps)	Efficiency (bits/Hz)	Receive (Mbps)	Efficiency (bits/Hz)
TECOM Ku-Stream1500	9.1	1.01	17.5	1.46	1.9	0.21	8.0	0.67
Tampa Microwave TM-65 (Legacy)	10.7	1.19*	19.5	1.63	3.75	0.42	10.0	0.83
Tampa Microwave TM-95 (Legacy)	10.7	1.19*	19.0	1.58				
Tampa Microwave TM-95 (Enhanced)	10.7	1.19*	26.0	2.17				
Tampa Microwave TM-130 (Legacy)	10.7	1.19*	29.0	2.42				
Tampa Microwave TM-130 (Enhanced)	10.7	1.19*	27.9	2.33				
L3-Communications Panther II - 60cm	10.7	1.19*	19.5	1.63				
L3-Communications Panther II - 95cm	10.7	1.19*	29.0	2.42				
Harris Seeker - 130cm	10.7	1.19*	29.0	2.42				
GATR Flex - 75cm	10.7	1.19*	29.0	2.42				

*The return rate (outbound) is a hardware limitation of the iDirect e850mp remote card whereas the maximum symbol rate of the return link is 7.5 Msps occupying 9 MHz. With newer e950mp remote cards, higher data rates can be achieved in the full allocated 12 MHz bandwidth.

Resiliency and Interference Mitigation

Engineered to support demanding government communications and applications, Intelsat Epic delivers reliability, security, performance, and the flexibility to keep pace with changing geographic and mission requirements. Intelsat Epic's spot beam design and advanced digital payload create an enhanced environment for battling interference and mitigating jamming, so government organizations are assured of secure coverage and connectivity for nearly any operation conducted in an environment anywhere in the world – without interruption.

Intelsat Epic satellites can successfully provide mitigation against interferences transmitted from both out-of-beam and in-beam locations. Out-of-beam interference mitigation is accomplished via the small spot-beam coverage design. As such, out-of-beam interference mitigation is always present and does not require any action from end users. In-beam interference mitigation is possible due to the capabilities of the digital payload on Epic satellites. Identification of the in-beam interferer and payload re-configuration by IGC personnel can mitigate interference in near real-time.

The resiliency of commercial SATCOM is an important feature for government customers and Intelsat Epic introduces an even higher level of protection than provided to date. Anti-jamming capabilities are greatly enhanced due to the low-probability of intercept (LPI) and jamming-resilience on Epic satellites. This improvement applies to all modem technologies deployed by end users. While frequency hopping modems provide some level of LPI, interference-mitigation, Epic capabilities such as on-board power monitoring and notch filtering of interferers as well as monitoring, and re-routing, means Government SATCOM Users are better protected in contested environments.

Security/Information Assurance

Intelsat's satellite communication network meets the DoD's strict information assurance standards, meeting and often exceeding DoD Directive 8500 and NIST Risk Management Framework (RMF) cyber security recommendations. Intelsat is also the only satellite operator with independent third-party Service Organizational Control 3 (SOC 3) accreditation, confirming that we maintain effective controls over the Satellite and IntelsatOne system and ensuring that it is protected against unauthorized access, use, or modification. Additionally, our state-of-the-art Intelsat General Secure Operations Center (ISOC) provides mission-critical support 24/7/365. Additional security measures employed by Intelsat General in the terrestrial segment include end-to-end protection and physical security at teleports.

The Protected Tactical Waveform (PTW) is not only enabled by Intelsat Epic, but has also been successfully tested on the Epic platform. PTW will provide cost-effective, protected communications over both government and commercial satellites in multiple frequency bands – C-, Ku-, Ka- and X-band. When PTW is transmitted over the Epic platform, the aforementioned space-based interference mitigation capabilities of Epic will further enhance PTW effectiveness.

Summary

HTS represents a quantum leap forward from the wide-beam technology that is the mainstay of government systems today. Although HTS architectures have been around for many years, until the launch of Intelsat Epic, it was impossible for the Government to reap the benefits of HTS since all HTS architectures were commercial-grade, closed-architecture designs with implicit vendor-lock and loss of control.

Intelsat Epic enables, for the first time, an enterprise-grade HTS open architecture that the Government can leverage to address the widest range of needs and applications. Intelsat Epic makes it possible for tactical SATCOM to achieve the well-established benefits of HTS without the satellite operator dictating the ground components used. It is now possible for the Government to operate a global-scale HTS network and deploy any variety of waveforms, modems, and terminals – of their choice. The case studies presented here quantify the benefit to the Government from HTS: higher data rates, increased spectral efficiencies, and advanced capabilities using existing, deployed assets can be achieved. Three examples consisting of emerging (TUAS), advanced (NOTM), and traditional (Ground) end-user applications, have been provided to underline the versatility of the Epic design in its ability to support small terminal sizes.

While other vendor-agnostic open architectures are appearing on the horizon, Intelsat Epic with its exclusive rights to the enhanced Next Generation WGS Boeing digital payload, is unique in offering any-to-any beam connectivity enabling militaries to incorporate Government teleports and existing hub infrastructure investments as part of their HTS realization.

The combination of vendor agnostic equipment and teleport location flexibility is unique to Epic and makes for a compelling value proposition for military and government agencies. This flexibility allows for HTS incorporation in the most seamless and cost-effective manner possible while remaining open to incorporate future advances in waveform technologies at the government's pace.

In this manner, while faced with the data-rate driven imperative of adopting HTS, Epic uniquely provides the highest level of control (vendor-choice, topology-flexibility, and ground-technology extensibility) among all HTS; making it ideally suited for military networks.

About Intelsat General

Intelsat General Communications (IGC) is a wholly owned subsidiary of Intelsat, the foundational architects of satellite technology. IGC provides government customers with mission-critical mobility communications solutions that include managed services with flexible pricing plans. From remote military outposts and disaster-recovery sites to U.S. embassies and homeland-security agencies, IGC solutions support and enable some of the most complex government applications. As the only commercial satellite operator with an independent third-party Service Organization Control (SOC 3) cybersecurity accreditation, Intelsat is uniquely positioned to help its government customers build a secure, connected future.

Imagine Here, with us, at www.intelsatgeneral.com.

INTELSAT General

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