BROADBAND SATELLITE SERVICE ARCHITECTURES – BROADBAND THAT MOVES TO WHERE THE FIGHT IS AND WHERE THE FIGHT WILL GO

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ABSTRACT

Today's warfighter view of satellite communications (satcom) is based on individual, independent mission-specific systems operating within an area of interest. These individual mission-specific operations are documented in the Satcom Database and are used by Office of Cost Assessment and Program Evaluation (CAPE) in assessing capabilities, requirement validation, and even Analysis of Alternatives (AoA). This is a bottom-up process driven by the historically high-cost, limited supply, and degraded threat environment performance of their satcom resulting in apportionment.

Today's "new space" commercial High Throughput Satellite (HCS) providers have a different view. A view of high affordability, essentially unlimited supply, and resilience or immunity to future threats, enabling new missions and capabilities that "old space" Satcom couldn't serve before. These new space systems are opening up new markets and revenue sources by creating capacity and capacity economics that enable new use-cases, like commercial airline passenger live streaming, that haven't been economical viable before.

Should the foundation analysis for the Protected Tactical or Wideband AoAs be the Satcom Database with individual, independent mission-specific use-cases and an apportionment model or should the foundation be based on future use-cases that can depend on assured, affordable capacity? And if based on future use-cases, what foundational baseline could be constructed to support assessing capabilities, validating requirements, and the Protected Tactical or Wideband AoAs?

We envision an AoA foundational baseline moving broadband satcom to where the fight is and where the fight will go. Defining layers of services, versus Satcom Database concept of layers of missions, extending down from space-based ISR; to high-altitude, medium-altitude, low-altitude ISR; to air, ground and maritime force operations and C2. This foundational baseline would define capacity or Gbps serving these layers, over areas of interest, and over timeframes or operational phases.

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Today's satellite communication systems support mission specific needs, such as Blue Force Tracking, Brigade Combat Team headquarters, Airborne ISR, Naval operations, C2, etc. Each of these individual systems, or use-cases, typically operate within the same area of interest and adversarial threat environment and are documented in the Satcom Database to be used by CAPE in assessing capabilities, requirement validation, and even AoAs. This is a bottom-up process driven by historically high cost, limited supply, and degraded threat environment performance that have caused existing satcom to be apportioned. But if satcom was highly affordable with essentially unlimited supply, and resilience to current and future threats enabling new missions and end-user capabilities, what would be the view from a Department or COCOM perspective? Would the problem be characterized differently? Would the use-cases and C4ISR architectures be structurally different?

The FY2015 and FY2016 National Defense Authorization Acts (NDAA) both directed the Department of Defense to trial or pilot the newest generation of commercial satellite communication services. New commercial HCS broadband communication services – widely known as “new space” – like those being offered by ViaSat and EchoStar/Hughes in North America, are providing ten to even over one hundred times, or “orders-of-magnitude,” improvement in performance and cost to the commercial broadband market. And potentially significant advantages to the warfighter and taxpayer.

These new services are providing true game-changing capabilities in the commercial broadband internet market, including broadband streaming to individual commercial airline passenger seats. For the Department, these services offer an opportunity to buy service subscriptions instead of employing Department purpose-built satellites or leasing geographically-specific Ku-band in MHz, then adding additional cost by building and operating its own networks on this bandwidth. The Department could subscribe to bits, very similar to the cell phone service model where a user is charged for the bits provided/used. Not only would these services provide connectivity anytime and at any location on the globe, they would also provide better performance and resilience, along with network management, visualization, control, and actively-managed cyber defenses.

The Department’s Deputy Assistant Secretary of Defense for Space Policy, Douglas Loverro, referred to these new commercial satellite communication services during testimony to the HASC Space Posture Hearing, stating that “technologies and opportunities of greatest significance for national security space today are being paced by advances in the commercial space sector.” Mr. Loverro went on to point out how profoundly different this is from when the Department led the way in national security space and just how promising these new commercial satellite communication services from Intelsat and ViaSat, as well as multiple entrepreneurial startups such as OneWeb and SpaceX, are in terms of capabilities and cost.

Despite the acknowledgement that these new space initiatives are developing technologies quicker and with superior capabilities, the Protected Tactical and Wideband AoAs due in 2016 and 2017 are being informed by the Department’s existing purpose-built satcom technology and leased Ku-band satcom technology via the Air Force Pathfinder Program. In its first four Pathfinders, the Air Force is acquiring more old space Ku-band MHz while forestalling analysis of new space services until 2019 and beyond. Thus, the current AoAs are based on a requirement and technology foundation defined by apportioned, expensive, limited, and threat-impacted old space satcom.

The industry voice coming out of the March Satellite 2016 conference at National Harbor was clearly that new space is lowering commercial satellite capacity pricing and enabling new markets like consumer internet and commercial airline passenger broadband that could be equally beneficial to the Department’s fixed and mobile satellite requirements.

This divergent view of old space versus new space was also visible when contrasting the statements by old and new space industry participants during the Future of Government and Military Space session moderated by the VADM Lyle Bien (Ret.). Old space said warfighters should be prepared to get less speed and capacity to gain more resilience while new space said warfighters should expect to get it all; more speed, more capacity, more resilience, and even more affordability. In old space the Department must choose or apportion, between speed and capacity, resiliency, and affordability while in new space the Department can have it all.

WIDEBAND AOA AND NEW SPACE

Fundamental to the AOA is data gathering or understanding the current state of the commercial satellite industry including the on-orbit implementations of commercial HCS broadband services that are delivering significant improvements in end-user speeds, anti-jam performance, and overall network resiliency, while lowering cost on a delivered-bit basis by more than orders-of-magnitude. The commercial industry is collectively supportive of the Air Force Space and Missile Systems Center (SMC), Military Communications Systems (MILSATCOM) Directorate's gathering data on industry's ability to support commercial satellite communication (COMSATCOM) Pathfinders in an effort to reduce the cost of current leasing rates and improve resilience to threats, including jamming and informing the AoA.

However, not gathering data on or piloting commercial HCS broadband systems exposes the Department to overpaying for the commercial satellite bandwidth they lease from commercial satellite broadcast providers. Even more importantly, this broadcast bandwidth that the Department uses today has now become the least resilient to interference and potential adversarial jamming. This was not the case 10 years ago. What happened?

It has been a little over 10 years since the first High Throughput Satellite (HTS), IPSTAR, went into service in Aug 2005 initiating a new era of satellite broadband. This established new satellite technology and techniques and associated ground architectures specifically designed to optimize two-way broadband communication; purposely maximizing end-user speeds and capacity, or pool of bits, that are generated for the total end-to-end investment including satellite, launch, insurance, ground segment, and operations.

Since that time, almost every commercial satellite service provider and every satellite manufacturer has engaged in some element of satellite broadband or HTS. Companies like EchoStar and ViaSat are completing their third generation HCS offerings, with each generation having better end-user speeds, capacities, availability, resilience, interference rejection, anti-jam performance, and cost-per-bit economics. Companies like Inmarsat are completing a first generation service constellation enabling ubiquitous global coverage.

During this same period, the Department launched its first Wideband Global Satcom (WGS) satellite in October 2007 and has continued a decade-long production program of virtually the same design with the launch of its seventh WGS in July 2015. So while the industry is "Reinventing Space" with improving cost-per-bit economics, availability, resilience, and end-user speeds and performance for broadband, the Department has continued to build and lease the same type of broadcast-centric technology and services capacity since 2005.

Today the industry is preparing for another decade of broadband innovation with multiple operators offering global constellations, each with further cost reductions, end-user speed and capacity increases, and improvements in availability and resilience. On the other hand, the Department is analyzing ways to harden the same broadcast-centric satellite technologies that they have purpose-built and leased since 2005. The end result is that the

Department now uses satellite technologies that are the most expensive, least abundant, and least assured communication capacity for providing two-way broadband.

Despite the acknowledgement that these new space initiatives are developing technologies quicker and with superior capabilities, the Wideband Analysis of Alternatives (AoA) due in March 2017 is being informed by the Air Force Pathfinder Program. A program that is acquiring more “old space” Ku-band MHz while forestalling analysis of “new space” services until 2019 and beyond.

There is a significant difference between the Congressional NDAA direction and the Air Force Pathfinder plans relative to the timing and importance of understanding these new commercial satellite communication systems. Instead of using the pilot funding to determine ways to better access these new commercial capabilities, the Air Force position is that they can learn the most by merely planning to acquire older leased Ku-band commercial satellite communication services, like the upcoming award of Pathfinder 2 later this year. This completely ignores the key question for Department on how best to leverage these advances as part of its resilience efforts. The DoD should pilot these operational state-of-art commercial satellite broadband technologies to determine if it can leverage them to ensure its warfighters have the best communications capabilities available.

FOUNDATIONAL BASELINE FOR AOA

Information dominance is foundational to military success and modern operations are dependent on having the necessary assured bandwidth for situational awareness, trusted intelligence, and efficient decision making. Our warfighters deserve the best communications capabilities and it’s our duty to provide it them. Our adversaries also rely heavily on the internet for their communications, command and control, information warfare activities, and to recruit new members. We know they have access to the global expansion of these commercial HCS broadband services offering performance speeds and resilience that exceeds that of our Department’s purpose-built and leased Ku-band services.

A key question becomes, is there a new foundational analysis for the Protected Tactical or Wideband AoAs that can move from the apportionment model of existing individual, independent mission-specific use-cases and onto a model of future use-cases that can depend on the availability of essentially unlimited global assured, affordable capacity.

In Exhibit 1, we visualize an AoA foundational baseline that considers moving broadband satcom to where the fight is and where the fight will go. Defining layers of services extending down from space-based ISR; to high-altitude, medium-altitude, low-altitude ISR; to air, ground and maritime force operations and C2. This foundational baseline would define capacity or Gbps to serve all of these layers, over areas of interest, and over timeframes or operational phases.

First consider that the conflict area can occur anywhere. The “eye of the storm” moves where the conflict is, and the capacity needs to move with the eye. This requirement will favor technologies and techniques that offer visible earth coverage enabling essentially global service, bandwidth allocation flexibility to move capacity to the conflict area, and standardized payload implementations that can greatly reduce satellite lead times.

Next, consider the multiple layers of services extending from space down to the ground. This requirement will favor technologies and techniques that offer the very best bandwidth economics both for available capacity and for affordable capacity, lowering spacecraft costs for affordable capacity, and continuing the trend of increasing capacity and employment of the cloud to greatly improve teleport system reliability, flexibility, and extensibility to meet ever-increasing capacity demands.

Finally consider the size of the eye of the storm, ranging from an entire regional theater down to a localized conflict. This requirement favors scale and wide industry participation. Exhibit 2 suggests the start of a capacity density construct for this eye of the storm. It contrasts two scenarios, a maritime conflict near a densely populated area and a more localized "Persian Gulf" like land and maritime engagement.

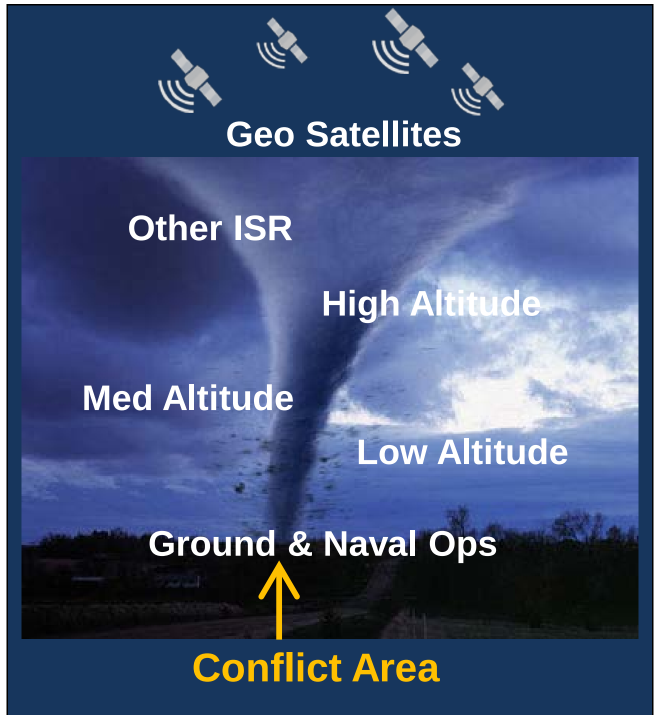

Exhibit 1: AoA Foundation – requirements defining the "eye of the storm."

In establishing a new foundational baseline for these AoAs the modelling needs to consider the capacity or Gbps to serve all of the users, user platforms, and even layers, over the areas of interest, and over the timeframes or operational phases. The data on the acceptable delivered rates of the commercial HCS services needs to be based on the 25+ Mbps services being provided to consumer terminals, 50+ Mbps services being provided to enterprise and emergency response terminals, and 100+ Mbps services being provided to individual maritime and airborne terminals. This market is dramatically different from the apportioned satcom market of the Department's existing purpose-built and leased Ku-band service.

Maritime Conflict Near Densely Populated Area	Persian Gulf Land/Maritime
• Carrier Battle Group (10 @ 100 Mbps) • High Altitude ISR (4 @ 300 Mbps) • Med Altitude ISR & C3 (10 @ 50 Mbps) • Low Altitude ISR (60 @ 20 Mbps) • Other ISR (1 @ 10 Gbps) • Heavy Commercial Capacity (500 @ 12 Mbps) • Possibly within 500 km (small number of beams) • A2AD Scenario (contested RF environment)	• 2 Carrier Battle Groups (20 @ 200 Mbps) • High Altitude ISR (4 @ 300 Mbps) • Med Altitude ISR & C3 (10 @ 50 Mbps) • Low Altitude ISR (60 @ 20 Mbps) • Other ISR (2 @ 10 Gbps) • Air Force Users (20 @ 100 Mbps) • Army/Marine Ground Users (300 @ 50 Mbps) • Within 750 km (multiple beams)

Exhibit 2: Hypothetical Capacity Density Models – initial modeling based on current and planned commercial HCS broadband platform delivery rates projects "eye of the storm" busy-hour capacity density well above 20-25 Gbps.

The Department should anticipate that these commercial HCS services will provide reduced rates on a delivered-bit basis and will also provide a corresponding increase/improvement in mission performance in terms of end-user speeds and network resilience. The Department should recognize that in order to take advantage of improvements in satellite technology and reap the significant return-on-investment that leveraging commercially available satellite technology would generate, they do not need to be the overall integrator and shouldn't use their existing deployed terminals as a rationale for a path forward, since both of these thoughts will resist leveraging the broader industry investment in these new broadband capabilities.

SUMMARY

The Congressional direction to fund pilots is directed at on-orbit, new space capabilities that are providing market-documented orders-of-magnitude improvements in performance and affordability in broadband delivery within the commercial market. The Pathfinders that the Department is implementing are all focused on acquisition mythology of "old space"; leasing Ku-band differently. The first Pathfinder that would pilot "new space" systems is planned for 2019. With the results of the Wideband AoA due in March 2017, these Pathfinders will not be able to inform the AoA on these new space capabilities. By itself, this would be unfortunate for all concerned, but the issue is further impacted by the rate of change in the broadband commercial satellite industry.

The first WGS satellite entered service in 2007 with 3.5 Gbps of busy-hour peak capacity. This was clearly on par with the industry. Since that time, numerous commercial HCS providers have implemented 60+ Gbps satellites and some have even implemented of 100+ Gbps satellites. In 2016, the second 150 Gbps class satellite will go into service and in 2017 the first 300+ Gbps satellite will go into service. And looking to 2019 and 2020, the industry is claiming global availability of multiple 1000 Gbps class satellites.

What this means to the AoA is that it not only needs to consider how to get informed on these new space on-orbit solutions, but also how to get informed on the industry's rate of change and potential capability of each of industry participant over the next few years. The capacity and cost metrics of new space are undeniable for Broadband delivery.

If we look beyond those metrics to resiliency, the new space systems have another advantage. As stated by the Deputy Assistant Secretary of Defense for Space Policy, it's one thing to eliminate the communication capabilities of a few centrally controlled satellites, while it's quite another to have to deny communications from dozens of commercial satellites all built by different companies and all operated independently.

To support the need to inform the AoA of today's on-orbit capabilities and to also provide a view of the next few years, Exhibit 3 provides a single company view. But the power of leveraging the commercial HCS industry for the Department's needs comes from extending this data past that of a single provider and augmenting the AoA with full participation of the industry.

Mission Attribute	DoD Purpose Built (AEHF & WGS) Global Coverage	Today – VS-1 / KASAT Multi-Regional Coverage (North America & Europe)	Circa 2017 – VS-1 / VS-2 Multi-Regional Coverage (North America, NAOR & Europe)	Circa 2020 – VS-3 Constellation Global Coverage (VS-1, VS-2, VS-3, Partners)
Network Capacity	22 Gbps on 13 Purpose-built Satellites • 3, MUOS at 0.12 Gbps • 3, AEHF at 5.4 Gbps • 7, WGS at 16.1 Gbps 15 Gbps of leased Ku-band satellite capacity	210 Gbps (2 Satellites) • VS-1 140 Gbps • KaSat 70 Gbps	560 Gbps (4 Satellites) • VS-1 140 Gbps • VS-2 250 Gbps • KaSat 70 Gbps	Over 3,560 Gbps (6 Satellites) • VS-1 140 Gbps • VS-2, 250 Gbps • 3, VS-3 3000+ Gbps • KaSat 70 Gbps
Network Coverage	Global • Full 65ºN to 65ºS • With 3 WGS and 4 AEHF	Multi-Regional • CONUS, Europe, Alaska, Hawaii	Multi-Regional • CONUS, Canada, Central America, Caribbean, Europe, MENA, Australia	Global • Full 65º N to 65º S • With 3 Satellites with more to follow
A/J Protection	WGS: • 10 Spot Beams per Satellite AEHF: • 2 Nulling Spot Beams per Satellite Leased Ku: • Wide beam, some steerable	80 Spot Beams per VS-1 Satellite • World leader in capacity with innovative spectrum re-use • Very large spectrum (1500 MHz) • Satellite technology provides superior resistance to uplink interference-confirmed by multiple independent studies	450+ Spot Beams (4 Satellites) 300+ per VS-2 Satellite • Dynamic redistribution of capacity • Improved A/J performance (more/smaller beams) • Larger Spectrum (2+ GHz) • Fault tolerant ground segment (gateway diversity) • Physical layer makes downlink interception/disruption difficult	1000+ Spot Beams per VS-3 Satellite • Dynamic redistribution of capacity AND coverage • Further Improved A/J (more beams / more beam flexibility) • Even Larger Spectrum (3+ GHz) • Fault tolerant, highly distributed ground segment
Network Visibility	• Carrier and Interference Visibility • Very Limited Network/Terminal Performance Visibility	• Real Time End-to-End Network Performance Monitoring and Management • Individual Terminals Individual end-user PEDs (>2 Million Daily)	• Real Time End-to-End Network Performance Monitoring and Management • Individual Terminals Individual end-user PEDs	• Real Time End-to-End Network Performance Monitoring and Management • Individual Terminals Individual end-user PEDs
User Terminal Speeds	WGS: 3-12 Mbps AEHF: • 75 bps - 2.4 kbps • 4.8 kbps-1.5 Mbps • 8.2 Mbps Leased Ku: • 128kbps- 12Mbps	40-100 Mbps	200+ Mbps	200+ Mbps
User Terminal Attributes	Large Terminal SWAP • 10-12 foot Antennas • $2.8B WIN-T RDTE • $2.2B FAB-T RDTE • $635M NMT RDTE	Small SWAP • 1-2 foot Antennas • PTW Over the Air Demonstration • No RDTE / NRE	Small Terminal SWAP • 1-2 foot Antennas • No RDTE / NRE • Portable / Nomadic Terminals • ESPA Flat Panel Antenna	Very Small Terminal SWAP • 1-2 foot Antennas • No RDTE / NRE • Portable/Nomadic & ESPA terminals
Capacity Cost	WGS: $172M / Gbps AEHF: $667M / Gbps • Plus $7.4B RDTE Leased Ku $247M / Gbps	$3.6M / Gbps	$2.1M / Gbps	Under $1M / Gbps

Exhibit 3: Time Phase Analysis – Department purpose-built and leased Ku-band baseline with evolving commercial HCS provider expanding market-funding capability.