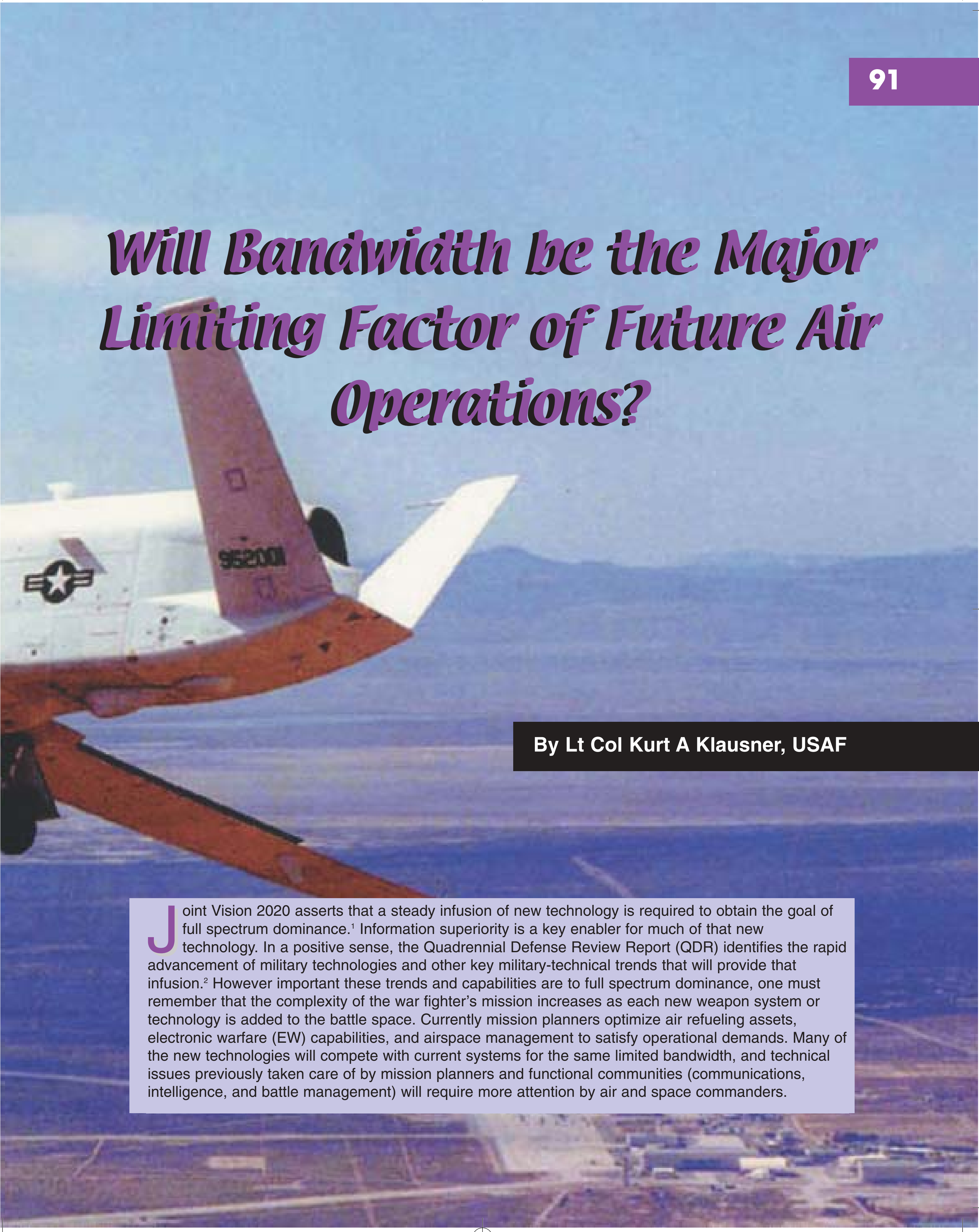

Will Bandwidth be the Major Limiting Factor of Future Air Operations?

By Lt Col Kurt A Klausner, USAF

Joint Vision 2020 asserts that a steady infusion of new technology is required to obtain the goal of full spectrum dominance.[1] Information superiority is a key enabler for much of that new technology. In a positive sense, the Quadrennial Defense Review Report (QDR) identifies the rapid advancement of military technologies and other key military-technical trends that will provide that infusion.[2] However important these trends and capabilities are to full spectrum dominance, one must remember that the complexity of the war fighter's mission increases as each new weapon system or technology is added to the battle space. Currently mission planners optimize air refueling assets, electronic warfare (EW) capabilities, and airspace management to satisfy operational demands. Many of the new technologies will compete with current systems for the same limited bandwidth, and technical issues previously taken care of by mission planners and functional communities (communications, intelligence, and battle management) will require more attention by air and space commanders.

Reconnaissance systems like the U-2 aircraft collected data in-theater, which was transmitted stateside, processed, and returned to the theater as information for the appropriate C2 and operational nodes

New weapon systems will place a significant strain on the finite bandwidth (limits in the radio-frequency [RF] spectrum and its associated data throughput or capacity) available within the battle space. As an example, the Office of the Secretary of Defense's (OSD) Unmanned Aerial Vehicles Roadmap 2000–2025, published in April 2001, identified 57 requirements associated with 15 related mission areas for unmanned aerial vehicles (UAV).[3] Weapon-system developers and campaign planners must analyze these requirements to integrate UAV capabilities effectively into the overall theater concept of operations. As their unique capabilities are recognized, the number of UAVs employed in future joint campaigns will continue to increase and drive a significant increase in required bandwidth. To the degree this need is not fully satisfied, commanders will be forced to make choices and trade off various systems when employing future forces.

War-fighting concepts will also place a significant strain on the finite battle-space bandwidth. The global strike task force (GSTF) concept of 'reachback' leaves much of the support operations behind in an effort to reduce the forward-deployed footprint. In addition to reachback, Air Force Doctrine Document (AFDD) 2-8, Command and Control, describes distributed operations as independent or interdependent nodes that participate in the operational planning and decision-making process to accomplish missions for engaged commanders.[4] A split operation is a type of distributed operation usually used to describe a single command and control (C2) entity that is physically split between two or more geographic locations. The commander must have the same degree of control over these operations as if they were collocated. The communications between the forward-deployed forces and their C2 and support centers place a heavy demand on C2 systems — particularly communications capabilities. The employment of these new war-fighting concepts, like that of UAVs, is possible only if they have access to sufficient bandwidth. For instance, the federated intelligence support for Operation Allied Force (OAF) required connectivity between American key centers of excellence throughout Europe and the United States. Each of these centers contributed a portion of the total support requirement, and all pulled together through robust communications systems. At a more tactical level, reconnaissance systems like the U-2 aircraft collected data in-theater, which was transmitted stateside, processed, and returned to the theater as information for the appropriate C2 and operational nodes.[5]

A commander must have a good understanding of what ‘bandwidth’ represents to make trade-off decisions on different types of capabilities. However, for purposes of this discussion, one needs to understand only the basic concept. Logisticians, for example, express the number of short tons of logistic throughput as C-5 aircraft equivalents. The vision of a C-5 conjures up three important aspects of transportation: capacity (an aircraft load), overall capability (total number of available airframes and sortie rates), and cost. Using this analogy, a commander immediately understands what it takes to move his or her requirement forward in terms of time, cost, and level of effort. Unfortunately, a similar analogy does not exist for bandwidth although one could use the airlift comparison to illustrate some aspects of bandwidth. For example, the complexities of getting diplomatic flight clearances are very similar to those of getting host-nation or several nations’ approval to use specific signals and frequencies. Likewise, the maximum number of aircraft allowed on the ground is similar to the restriction on ground-terminal communications capabilities. Simply put, the greater the volume of information to be transmitted, the larger the requirement for bandwidth to move it – higher bandwidth allows faster transmission of information. To help understand the discussion below, one should consider a megabit per second (1 Mbps) as a bandwidth yardstick to represent data throughput in much the same way the C-5 equivalent analogy is used to quantify logistic throughput.

UAV BANDWIDTH ISSUES

Combatant commanders identify and prioritize their war-fighting shortfalls and requirements on the integrated priority lists (IPL): ‘Of the 146 requirements submitted in the combined 1999 Integrated Priority Lists for funding in the FY02–07 Future Year Defense Plan (FYDP), 57 (39 percent) identified needed capabilities that have previously been associated in some form …with UAVs… These 57 requirements can be organized into 15 mission areas’[6] (fig. 1).

15 UAV-related mission areas

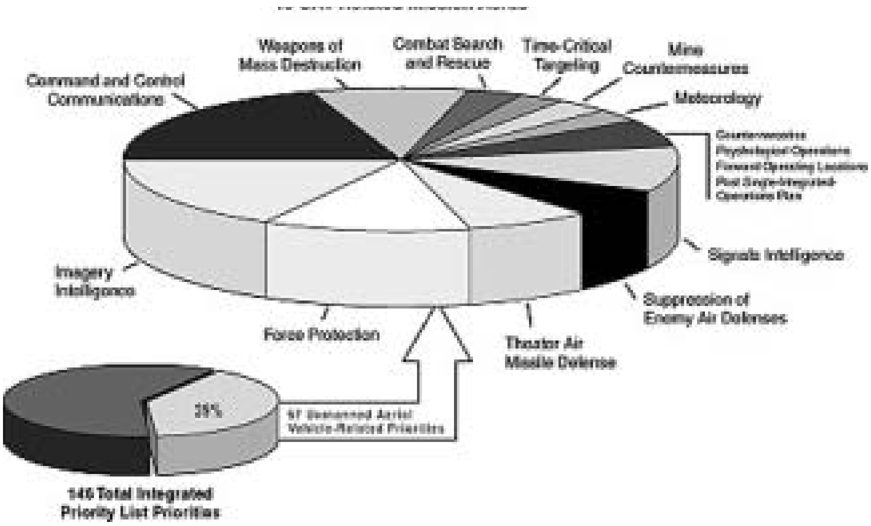

Figure 1. IPL Priorities Link to UAV Missions (From Office of the Secretary of Defense Unmanned Aerial Vehicles Roadmap 2000–2025 (Washington, D.C.: Department of Defense, 6 April 2001)

Hunter UAV

Even with only a few UAVs operating in Kosovo, communications systems were stressed to the point that operational trade-offs were required and some activities had to be delayed or cancelled

UAVs will clearly become critical weapon systems in the future. Mission-area proponents will compete for UAV capabilities, and all will need bandwidth to support vehicle operations and payload processing. Likewise, UAVs will compete with other systems for their place in the battle space.

European Command (EUCOM) operated two Predators simultaneously from Bosnia during OAF. Each needed 6 Mbps to support video dissemination within the theater and the United States, a requirement that severely stressed the Defense Information Systems Network architecture and necessitated preemption of lower-priority channels while the UAVs were in flight. Maintaining a quality link with Beale AFB, California (the site where the Predator achieved its initial operational capability), remained problematic throughout the campaign.[7] In addition to Predator, two Hunter UAVs flew from Macedonia, and each one required an additional 6 Mbps of bandwidth. When both Predator and Hunter moved from reconnaissance to targeting roles, communicators scrambled to increase the reliability of the Very Small Aperture Terminal (VSAT), a satellite communications system that handles data, voice, and video signals.[8] Even with only a few UAVs operating in Kosovo, communications systems were stressed to the point that operational trade-offs were required and some activities had to be delayed or cancelled.

The combatant commander of US Central Command (CENTCOM) deployed both the Global Hawk and Predator systems to support Operation Enduring Freedom (OEF). Because the operation is ongoing, details of the supporting architecture are classified. However, one can conclude that bandwidth requirements are far greater than those required for Kosovo operations. Lt Gen Harry Raduege Jr., director of the Defense Information Systems Agency (DISA), observed 'Today, in Operation Enduring Freedom, we're supporting one-tenth the number of forces deployed during Desert Storm with eight times the commercial SATCOM bandwidth.'[9] Additionally, 'Global Hawk consumed five times the total bandwidth used by the entire US military in the Gulf; and operations in Kosovo used 2.5 times what was used in the Gulf War.'[10] The OSD UAV Roadmap adds support for additional bandwidth: 'The shortage in long haul, wideband over-the-horizon communications will be exacerbated as future intelligence, surveillance, and reconnaissance (ISR) platforms, manned and unmanned, are fielded. . . . This shortage takes two forms, insufficient bandwidth and lack of coverage in some geographic areas, which can directly constrict global UAV deployment. This infrastructure needs to be increased as these platforms, including UAVs, are fielded.'[11]

The frequency spectrum is a battleground between competing interests. Governments who control the use of the spectrum are under increasing pressure to ‘sell off’ additional bandwidth to commercial interests. The remaining smaller portions of the spectrum have become more difficult to deconflict. One such conflict exists between the Federal Aviation Administration (FAA) and the Department of Defense (DOD), the latter successfully obtaining 51 channels within the 960–1215 megahertz (MHz) band from the former to use for the Joint Tactical Information Distribution System (JTIDS). These channels, located within the L-band of the spectrum, were normally reserved for aeronautical radio navigation equipment.[12] The bandwidth capacity at this frequency range is limited between roughly 600 bits per second (bps) and 300 kilobits per second (Kbps) (roughly a C-130 aircraft equivalent if one uses the C-5 analogy) and, therefore, is not capable of fully supporting UAV ISR payloads.[13] Competition within DOD for the same limited bandwidth, particularly to support each service’s JTIDS, indicates that the network will be near saturation when key weapon systems are deployed (fig. 2).

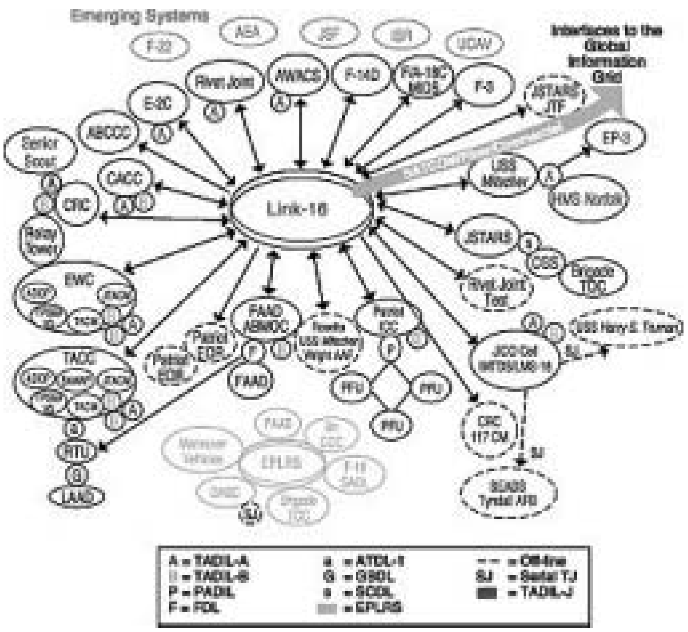

Figure 2. Proliferating Data Links, Protocols, and Systems (From briefing, Col Michael B. Leahy, PhD, USAF, subject: Unmanned Combat Aerial Vehicle [UCAV] Day-in-the-Life, UCAV C4ISR Overview, May 2001)

Frequency management also plays a critical role when one supports operations that rely on using the RF spectrum. During OAF, frequency coordinators deconflicted 44,000 frequencies — a monumental task.[14] Additionally, the Kosovo campaign revealed that the safe and effective employment of UAVs required that they fly at the same time, be able to adjust their mission timing and targeting (rolexing), and expand the UAV sensor’s field of view to give the operator greater situational awareness.[15] Deconflicting frequencies becomes even more problematic when the bandwidth requirements to support these operational needs are added together. Anticipating the increasing number of possible UAV and unmanned combat aerial vehicles (UCAV) missions in the future, planners must place special emphasis on dynamic bandwidth management.

Despite impressive military systems and capabilities, many of today's requirements can be met only by the use of leased commercial satellite systems

KICKING DOWN THE DOOR REQUIRES BANDWIDTH

Providing sufficient bandwidth to support forward operations has always been a challenge. Communications satellites have become the workhorses in this area due to their effectiveness and efficiency. The Defense Satellite Communications System (DSCS) serves as the mainstay of DOD satellite communications by providing dedicated superhigh frequency (SHF) capacity. Geostationary ultrahigh frequency (UHF) satellite systems also play heavily in DOD's C2 arena. Despite these impressive military systems and capabilities, many of today's requirements can be met only by the use of leased commercial satellite systems.[16]

OPERATION DESERT STORM

Satellites were the most important factor in extending communications to the Persian Gulf area of operations. During peak capacity, DSCS provided 75 percent (68 Mbps), and NATO furnished an additional 5 percent of the SHF bandwidth. The final 20 percent of the required bandwidth needed to support the theater's over 2,000 ships, submarines, aircraft, and ground forces was leased from commercial systems.[17] The key point is that very little communications infrastructure existed in the theater prior to initiation of the conflict.

OPERATION ALLIED FORCE

Communications systems supporting the combat operations in Central Europe remained saturated throughout the conflict. Kosovo air operations required more than twice the bandwidth used to support all the forces in Operation Desert Storm. The growth in these demands required extensive coordination among all participants to optimize the allocation of the available bandwidth. Just as Desert Storm was dubbed the 'first information war,' so OAF was labeled the 'first video war' by the European Command's director of Command, Control, Communications, and Computer Systems (ECJ6). OAF extensively used video teleconferencing and videotaped Predator operations.[18] To provide the data throughput to make this possible, DISA contracted for over $20 million worth of commercial bandwidth during the 87-day conflict.[19]

OPERATION ENDURING FREEDOM

Current OEF operations in the CENTCOM's area of responsibility (AOR) have similarities to OAF, Desert Shield, and Desert Storm. As in OAF, OEF operations have elements of forward deployed operations, distributed operations, and reachback operations. Global strike missions that originated from the continental United States (CONUS) also required connectivity. As was the case in the Persian Gulf conflict, the Afghan theater had little existing bandwidth capacity or satellite infrastructure. The requirement to support extensive video and ISR data rates challenged the responsible parties.

The GSTF concept provides a lethal joint-battle-space capability by combining stealthy aircraft employing advanced weapons with a multisensor command and control constellation (MC2C). The MC2C is a horizontally integrated architecture of C2 and ISR capabilities.[20] Bandwidth is a key enabler for communications connectivity and fundamental to the GSTF concept. Coupling this MC2C requirement with the considerable amount of bandwidth consumed by UAVs, makes apparent the fact

The USAF concept 'One Air Force, One Network' envisions an information-transport capability that integrates the links – from the kill-chain to reachback for the expeditionary air and space force

that bandwidth allocation and management are now as operationally important as airspace control and the allocation of tanker, jamming, and defense-suppression assets.

The USAF concept 'One Air Force, One Network' envisions an information-transport capability that integrates the links – from the kill-chain to reachback for the expeditionary air and space force.[21] In addition, the concept seeks to enhance the connectivity from the last switch to the actual end user, the last aerospace mile, with improved data links to weapon and ISR systems. This concept's objective is to provide a seamless, streamlined communications infrastructure that uses bandwidth efficiently.[22]

Operational concepts and new systems have been developed with the assumption that adequate bandwidth will be available. The emerging employment concepts for UAVs and the GSTF reflect this assumption and reinforce the need for commanders to become more aware of the demands being placed on bandwidth and the finite frequency spectrum. Unfortunately, commanders will have to establish priorities, oversee bandwidth allocation, make decisions on trade-offs, and understand the operational consequences.

BANDWIDTH AND THE JFACC

The joint force air component commander (JFACC) orchestrates the theater air campaign to support the combatant commander's overall campaign plan. To help understand why the JFACC must help shape the bandwidth architecture, the reader should be aware how this service is provided today. Once that picture is clear, it should be easy to understand why it is necessary for the JFACC to be involved in the trade-offs necessary to reconcile future bandwidth requirements and limitations, and how that process should become an integral part of the planning routine.

The senior representative of the communications and information community (A-6) makes today's bandwidth available to the JFACC, just as other specialists make other capabilities available. Numerous supporting organizations facilitate this process, but the overall architecture is handled mainly within the communications channels. Fortunately, most of the current issues regarding limited bandwidth can be worked at lower levels. One JFACC, commenting on his recent war-fighting experience, suggested that he never had to worry about trade-offs because his senior communications (A-6) and intelligence (A-2) representatives figured it out at their level.[23] Unfortunately, the complexity of future bandwidth requirements will not be so easily dismissed.

Communications architectures perform best when they are stable, the reality is that technology is very dynamic and that the current electronic environment (as well as software) does not appear structured to cope with the inevitable change

The A-6 serves the JFACC or the commander, Air Force forces (COMAFFOR) by providing communications as well as electronics and automated information systems. One significant responsibility of the A-6 includes establishing the theater architecture to support operational and command requirements. Other critical responsibilities include coordinating with representatives of other command and supporting organizations such as the joint force commander's director of command, control, and communications systems (J-6) and DISA. The A-6 must ensure that users of allocated and assigned bandwidth are deconflicted, that they meet technical parameters, and that interface requirements are satisfied. In addition to advising the air operations center (AOC) on communications architectures that support the joint air operations plan, the A-6 extends required communications to subordinate units and other components.[24] Thus, the A-6 performs vital roles throughout the planning and execution processes, but he or she is not typically part of the joint air operations plan and master air-attack-plan development process – which is currently not a limitation.

Providers of communication systems form a key joint air operations center (JAOC) support team and are organized as the communications focal point, help desk, JAOC networks and system administration, and communications equipment support. This support team typically provides not only systems and services to the JAOC divisions but also helps select the frequencies to be used in the air tasking order, air control order, and the communications tasking order. The team coordinates all JAOC command, control, communications, and computer (C4) requirements; manages C4 activation, restoration, and performance; interfaces with all JAOC C4 system users; controls network functions; and keeps the Theater Battle Management Core Systems (TBMCS) running. Requests for more bandwidth, additional frequencies support, or other C4 support are made to the communications focal point, who then forwards the requests to the responsible agencies.[25]

Several additional issues associated with JAOC operations should be considered in the discussion of bandwidth. One must give some thought to managing the increasingly complex data-link architecture as

Bandwidth and frequency requirements are increasingly global in nature as evidenced by the nonstop Global Hawk flight from the CONUS to Australia

additional types and numbers of assets are added to the networks. The current manager–the joint interface control officer–has his or her hands full reconciling the requirements associated with providing situational awareness throughout the system (see fig. 2). Likewise, successful management of intelligence-collection processes ensures that the right resources look at the right targets at the right times, deconflicts unnecessary overlap, and fills gaps in coverage. The increased resolution and fidelity of future collection systems not only will require greater bandwidth but also will compete for access to the limited number of common ground stations. While communications architectures perform best when they are stable, the reality is that technology is very dynamic and that the current electronic environment (as well as software) does not appear structured to cope with the inevitable change.

Additionally, bandwidth and frequency requirements are increasingly global in nature as evidenced by the nonstop Global Hawk flight from the CONUS to Australia. This significant capability and mission duration can also exceed the current Air Tasking Order 24-hour day. JAOC processes should be changed to accommodate the long flight times associated with UAV mission capabilities.

RECOMMENDATIONS

Bandwidth and infrastructure must be expanded or used more efficiently (by changing processes and organizations) to implement new technologies and war-fighting concepts successfully. Currently, UAVs represent challenges and incredible opportunities, while new operational concepts such as the GSTF also create paradigm-changing possibilities.

However, both require bandwidth resources and infrastructures that exceed current capabilities. Adding more bandwidth through the use of satellites is expensive at best and still might not solve all the problems associated with GSTF and UAV operations (landing rights and so forth). Making trade-offs to accommodate UAV operations within the current bandwidth is a technical challenge. The fact that multiple UAVs will need to share the same frequency bands over time forces the JAOC to trade one mission for the next. Because only a finite number of UAVs can be operated at the same time, to get an additional UAV mission airborne, one has to be terminated. Actually, there is nothing new here other than advising the JFACC of the limitations and providing recommendations on how best to manage these resources to increase the effectiveness of the JFACC's efforts to meet the joint force commander's objectives. Another approach might be to develop a dynamic frequency and transponder allocation plan that would allow transfer of resources for different purposes. For instance, the commander could choose to allocate bandwidth to a UCAV mission and hold off on the video teleconference until the UCAV no longer needs the bandwidth. Finally, one could conceive of a JTIDS-type structure to support multiple UAVs, but it would have to be at a much higher frequency range to allow for adequate data rates. An ongoing effort by the Defense Airborne Reconnaissance Office (DARO) may overcome some of the obstacles associated with finding a frequency spectrum and agile communications equipment. That office sponsored a study to integrate a common data-link, high-bandwidth capability for airborne platforms. Possible solutions include laser communications technology that has transmission speeds in the 1-gigabit-per-second realm.[26] In addition, DARO is looking at a program to lease more satellite communications capacity and is attempting to develop an onboard UAV moving-target indicator that can be used to cue other onboard sensors, thereby reducing the demand for bandwidth.

Automation tools should be developed to help planners orchestrate the allocation of available bandwidth to achieve the best possible result. These tools would be similar to the airspace deconfliction tool used in TBMCS. The bandwidth-allocation tools would help planners to 'what if' various hypothetical scenarios and to point out problems (conflicting frequency assignments, not enough capacity, etc.). This capability not only is needed at the JAOC but also could be used at higher planning echelons where theaterwide — even worldwide — bandwidth allocations must be planned.

Increasingly, war-fighting capabilities depend on bandwidth for success. As GSTFs deploy and engage an enemy, greater coordination will be required between the communications and information professionals, the joint interface control officer, battle-management specialists, and the collection-management community. JFACCs must be aware of all of their forces' vulnerabilities as they integrate this knowledge into their planning and execution efforts. For example, the loss of a satellite that provides bandwidth could have a devastating impact on the ability of an engaged GSTF to operate UAVs. The commander must weigh these risks in much the same way he or she would assess the risks associated with EW vulnerabilities. While Mbps correctly specifies data-transmission rates, it does not readily translate an understanding of operational capability to the layman. It would be helpful to have a simple, well-understood unit with which to convey bandwidth requirements so that even those without an electrical engineering degree can readily understand them. The search should continue for an +-analogy similar to the logistics 'C-5 equivalent' expression of capability.

CONCLUSIONS

New weapon systems and war-fighting concepts, like UAVs and the GSTF, place significant demands on future battle-space bandwidth. Commanders must be aware of this growing dependence on bandwidth and the limitations in the RF spectrum and data-throughput capacity. As a consequence, significant trade-offs may be required when employing forces in the future. Developers of new weapon systems that will require bandwidth should also design tactics and techniques to minimize the demands on this limited resource. New organizational processes and tools are required to manage the complexity of optimally allocating bandwidth. JFACCs must also understand the risks and the opportunities involved with operations that depend heavily on bandwidth.

Successful employment of military force in the future will require the optimum use of bandwidth. Now is the time to put the bandwidth tools and processes in place that will make victory a certainty.

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