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AIR COMMAND AND STAFF COLLEGE

AIR UNIVERSITY

COMMAND & CONTROL 2010:

THE IMPACT OF EMERGING COMMERCIAL SATELLITE SYSTEMS ON JOINT OPERATIONS

by

Virginia B. Ashpole, Maj, USAF

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

Advisor: Lt Col Theresa R. Clark

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Disclaimer

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Preface

I chose this research project because I was eager to learn more about the current evolution of commercial satellite services. Commercial industry is pioneering satellite technology with new capabilities. Systems like Iridium and Teledesic promise to change the world for all its inhabitants with their ubiquitous availability and affordability. As the remote corners of the world become connected into the global infrastructure, the emerging omnipresence of these satellites has implications for how the military conducts its missions. Command and control is only one of the many aspects of military operations which will be affected.

I would like to thank my research advisor, Lt Col Theresa Clark for encouraging my interest in this subject, for her dedicated critiques, and her support when the effort became tiring. I would also like to thank Maj Gen John Woodward, Jr. for providing his insights. There are many who have inspired me to this project: Cindy Raiford of OSD; Bill Harding and Glenn Whited of Motorola; Marlin Forbes of Tricor; Bob Sims; Mark Adams of Mitre; and Nancy Snowhook of Aerospace to name a few. I dedicate this paper to the team of people, both government and contractor, who work to provide better communications for the Department of Defense.

Abstract

Joint Vision 2010 depicts a military with unprecedented mobility, precision, and dispersion of force. To achieve this vision, the existing command and control structures and systems must evolve to support greater information flows to a wider audience. This paper examines the potential utility of emerging commercial satellite systems to military command and control of joint operations.

Emerging commercial satellite systems offer worldwide communications and remote sensing services previously unavailable commercially. These services include mobile voice and data, direct broadcast, broadband communications, and remote sensing. This paper examines the architecture of several emerging satellite systems and highlights attributes and capabilities which provide particular advantage for directly and indirectly enhancing the command and control of joint operations. In addition, an assessment of commercial systems in terms of assured access, security, and interoperability is discussed.

With modifications for military unique requirements, the emerging commercial satellite systems can help achieve the command and control of military forces envisioned in *Joint Vision 2010*. These systems represent a pre-deployed, robust, and interoperable infrastructure which the military can leverage to its benefit.

Chapter 1

Command & Control 2010

War is about people, not computers, and only a human can understand. Focusing on understanding is the way to make information technology really relevant to warfare.

—Defense Science Board

It was 0800, January 10th, 2010. Maj John Fisher prepared to give the introductory briefing on Operation NEW WAVE. He mentally reviewed the charts and figures as the new JFACC, Brig Gen Don Hall arrived.[1] "Let's get this going" the general said as he took his seat. Maj Fisher had barely finished briefing the expected wind and precipitation, when the general signaled him to stop. "I don't need a lot of facts and figures. Can you tell me if my AWACS and Raptors can fly and what my sensors can see? And what's the enemy up to? I know you're a smart guy, but I don't need data. I need a picture. Paint me a picture, okay?"[2]

The operation was underway. In his Joint Air and Space Operations Center, Col Billy Spencer observed with satisfaction the movement of aircraft and the tracks of space systems on the 120 inch flat computer display. The situation room screen showed the entire theater of operations: a map with roads and installations highlighted by the latest intelligence on friendly and enemy forces. In addition, each sortie planned in the current Integrated Air and Space Tasking Order was plotted and numbered with the status color-coded. You could turn off the ITO display or set it for one of the next two cycles.[3] Next to the screen was a bank of computer terminals logged into the theater database. He could view almost instantly any individual piece of data that had been entered into the system by any means. He had access to text, imagery, live and recorded video and audio, DIA briefings and summaries, CIA reports, and NIMA charts and maps.[4] With a little effort, he could get satellite feeds and live and recorded aerial reconnaissance.[5] And of course, he could watch the latest CNN update.[6] There was plenty of information available; the key was figuring out what was important and what it meant.[7]

The pair of Joint Strike Fighters was making its approach on the 4th Street bridge. The destruction of the bridge was a key step in the effort to isolate enemy forces within a smaller area of the city. The approach area had been swept earlier by Raptors and, after analysis of intelligence surveillance and reconnaissance, had been declared "clear."

CPT Gordon Upton looked up from his laptop display. The green coloring on the display map indicated an area which was known to be free of enemy forces, but it was always best to be cautious. A vibration on his belt pager told him he had an urgent update. "Colonel says we need to advance to the rail yard on 15th Street. Let's take it a block at a time and keep it low." They moved quickly into the cleared area. One of CPT Upton's men pulled him aside. "Sir, I saw a cigarette flare up on the near side of the block buildings ahead—this area's not as clear as headquarters thinks." The squad leader thought about the possibilities. It could be a stray non-combatant or a friendly unit in the area. Coalition forces were everywhere and, while technology had made it easier, coordination remained incomplete. There was also the possibility of some residual enemy force; but with the numerous sensor sweeps, it was unlikely anyone left would be much of a threat. "Let's approach from the side and see if we can get a closer look." As they approached the block buildings, they caught a glimpse of a soldier with a man-portable air defense system. "Look, Captain—it's a Desolation MANPAD! I didn't know those were out yet!" The Desolation MANPAD was the new high velocity, high altitude, surface-to-air man-portable missile that had been developed in China.[8] Its distinctive silhouette left no doubt of its identity; the MANPAD would be a deadly threat to the fighters in the area.

CPT Upton opened his laptop and entered the red symbol for enemy MANPAD on his current location. It was dangerous to send a transmission from his exposed location with all the sensor technology which both enemy and friendly forces used, but with the satellite systems and the spread spectrum technologies, the threat of interception and location was acceptable given the situation.

Col Spencer watched the approach of the strike fighters toward their objective. Suddenly an enemy alert flashed on the screen—MANPADs on the approach. He knew the JSF pilots would be seeing the same update on their heads up display. Lead pilot Ted Forbes hailed his wingman, "Keep an eye out to the right—MANPADs spotted." As he saw the bright flash of a launch, he released his pre-emptive flares and rolled left. Both fighters narrowly evaded the missile and proceeded to the bridge. After launching their PGMs, they watched, with satisfaction, the bridge implode as they headed back to base.

Statement of the Research Question

The scenario provides a glimpse into a future world with ubiquitous communications and sensors; but one still dependent on individual judgement and insights. How will emerging commercial satellite systems change military command and control of joint operations in 2010? *Joint Vision 2010* depicts a US military which dominates the battlespace with Dominant Maneuver, Precision Engagement, Full-Dimensional Protection, and Focused Logistics. To achieve this vision, the military will require major advances and new approaches to command and control to enable the synchronized effort of situationally aware, dispersed, and highly lethal forces. Emerging commercial satellite systems may provide a vehicle for achieving the advances in command and control for this vision. This paper will examine the new capabilities becoming available commercially, their impact on command and control within the military, and explore the implications of using commercial systems for command and control purposes.

Background and Significance of the Problem

In 2010, there are projected to be well over 1000 new commercial satellites in use.[9] A large number of these systems will provide communications—anything from kilo-bit per second pagers to multiple giga-bit per second telecommunications switching trunks which can support an entire base.[10] A few of the new systems will provide commercial sensor services: primarily imagery, weather, and positioning. Some of these systems will offer advantages that do not exist today or exist only in specialized government systems. These advantages, soon to be available in commercial-off-the-shelf systems, include worldwide coverage (even some with polar coverage), impressive system robustness, and small handheld terminals which can communicate on the move.[11]

The vision of the future, articulated in *Joint Vision 2010*, is a military that dominates the battlespace with increased stealth, mobility, dispersion, and higher operational tempo.[12] Advances in command and control will be necessary to achieve this vision of fluid dominance. In order to provide timely situational awareness to make decisions and to synchronize dispersed forces, communications with assured access, security, and interoperability are required. In addition, advances in commercial remote sensing systems can provide unclassified sources of current intelligence.[13] The availability of these commercial systems offers new choices to the military to achieve its command and control vision of the future. This paper will examine whether commercial satellite systems provide an acceptable capability to enhance command and control to meet the requirements of this vision.[14] Further it will discuss how command and control is both changed and unchanged by the use of these emerging systems.

Limitations of the Study

This study will examine broad categories of commercial satellite systems, using a few systems as examples, and draw general conclusions about their architectures, services, and utility. It will consider not only those assets which are used for command and control, but also those capabilities which enhance command and control by improving the knowledge available for decision-making. It will not provide a detailed cost-benefit of commercial satellite systems nor compare them directly to specific military systems. Finally, this study does not explore the role and importance of the organizations and exercises which address the development of these issues and concepts.

Definitions and Terms

A glossary of terms is provided at the end of this paper. Appendix A provides an overview of basic satellite terms and concepts, including orbits such as geostationary, medium earth, and low earth; and communications terms. Appendix B summarizes the commercial satellite systems currently projected. Appendix C provides additional information on the Global Broadcast Service.

Preview of the Argument

Emerging commercial satellite systems have evolved to support the growth of multinational corporations and requirements of a mobile business force, providing new services previously only available through military-unique systems. Current satellite industry summaries show communications services with increased mobility, coverage, and capacity, in addition to commercial intelligence products, will now be available directly to consumers. Further examination of the architecture of a number of these commercial satellite systems, as described by their literature and web sites, provides an understanding of the significance of the design architecture's impact on capabilities. To assess the impact of these new capabilities on military command and control and the acceptability of commercial satellite systems for military use, these systems are examined in terms of assured access, security, and interoperability.

Reliability requirements of the marketplace have driven impressive system robustness against failure or damage. Built for commercial customers, these emerging systems are easy to use and interoperable. With modifications for military unique requirements, emerging commercial satellite systems can greatly enhance the availability of information and can contribute significantly to future command and control.[15] Their use can increase the availability and audience of information available to support and execute decisions. It is important, however, to understand the limitations of these systems and the continuing importance of human judgement and initiative.[16]

Notes

[1] In order to maintain the flow and realism of the scenario, acronyms are not explained in order to reflect normal spoken usage. To assist the reader, definitions for each acronym used are provided in the glossary.

Notes

[2] The scenario is based in style, concept, and to a lesser extent wording on Operation VERBAL IMAGE of Marine Corps Doctrinal Publication (MCDP) 6, *Command and Control*, HQ US Marine Corps, 4 October 1996,1-32.

[3] With better capabilities for command and control in 2010, it is plausible that multiple and dynamic Integrated Air and Space Tasking Order (ITO) cycles per day will be generated instead of the current system of one ATO execution per day.

[4] These types of products are currently being sent today on the Joint Broadcast Service as part of the Bosnia Command and Control Augmentation.

[5] Live Predator Unmanned Airborne Vehicle video is currently being collected and broadcast over Bosnia in near-real time using the Joint Broadcast Service. Reference Bob Brewin, "Special Report: Bosnia," *Federal Computer Week*, Supplement, 29 April 1996, S12.

[6] CNN is received in most command centers today. For example, it is used in Cheyenne Mountain, aboard Carrier Battle Groups, and is watched throughout the Pentagon.

[7] It is possible in 2010 that there will also be integrated decision aids as well as integrated information displays for decision makers. While data fusion should be more mature by 2010, I would expect that it will take longer for useful decision aids to evolve because of the tremendous variety of situations which can occur.

[8] MANPADs, such as the SA-7 and SA-9, exist today which are low-to-medium altitude man-portable anti-aircraft missiles. Technology to increase the range to higher altitudes can reasonably be expected to emerge in the next 12 years.

[9] Marco A. Caceres, *World Space Systems Briefing*, (Fairfax, Virg.: Teal Group, May 1996), GEOSTATIONARY Commercial Communications Satellites Market Overview 1-9, LEO/MEO Commercial Communications Satellites Market Overview 1-6. This is impressive considering there are only about 500 satellites in orbit today.

[10] Kilo-bit per second = 1000 bits per second; giga-bit per second = 1,000,000,000 bits per second.

[11] Worldwide coverage is used here to denote coverage between 65 degrees north latitude and 65 degrees south latitude around the globe. Global coverage is used to denote coverage between 90 degrees north latitude and at least 65 degrees south latitude around the globe.

[12] *Joint Vision 2010* (Washington, D.C.: Office of the Joint Chiefs of Staff, 1995), 14.

[13] Joseph C. Anselmo, "Commercial Satellites Zoom in on Military Monopoly," *Aviation Week & Space Technology*, 22 September 1997, 75.

[14] The determination of "acceptable" will be based on assured access (to include reliability, availability, and ability to degrade gracefully when stressed by failure or damage), security, and interoperability.

[15] In order for commercial satellite systems to meet military requirements, the DOD will need to proactive in communicating those requirements and, in most if not all cases, bear the costs of designing and implementing military-unique features.

Notes

[16] Commercial satellite systems worth billions of dollars can be modified to meet military needs for tens of millions of dollars. This provides enormous leverage for the defense dollar in terms of capabilities.

Chapter 2

Commercial Satellite Technologies and Systems

> *All around our planet, your telephone conversations, facsimiles, data or paging messages will soon be freed from wires, weather, and geography. Using a hand-held satellite phone, and a constellation of 66 low earth orbit satellites, you'll soon be able to communicate with anyone, anytime, virtually anywhere on earth.*
>
> —Iridium Brochure

DOD requires a variety of communications to meet the needs of our forces in peacetime and across the spectrum of conflict. While no single commercial systems is appropriate for all situations, the emerging commercial satellite systems offer a variety of services of interest to the military.

The Teal Group Corporation estimates that over 1100 satellites valued at approximately $40B will be launched between 1998 and 2005.[1] Over 200 of these will be geostationary satellites and over 900 will be low earth orbiting (LEO) satellites, primarily providing communications services.[2] Generally, for communications between fixed points in the same portion of the globe, geostationary systems are sufficient and cost-effective. For more complex communications requirements and global coverage, LEO and medium earth orbiting (MEO) systems may provide better performance.[3]

Of the 1100 satellites projected, over 800 are expected to be manufactured by United States companies.[4] Many of the LEO and MEO systems are owned and operated by

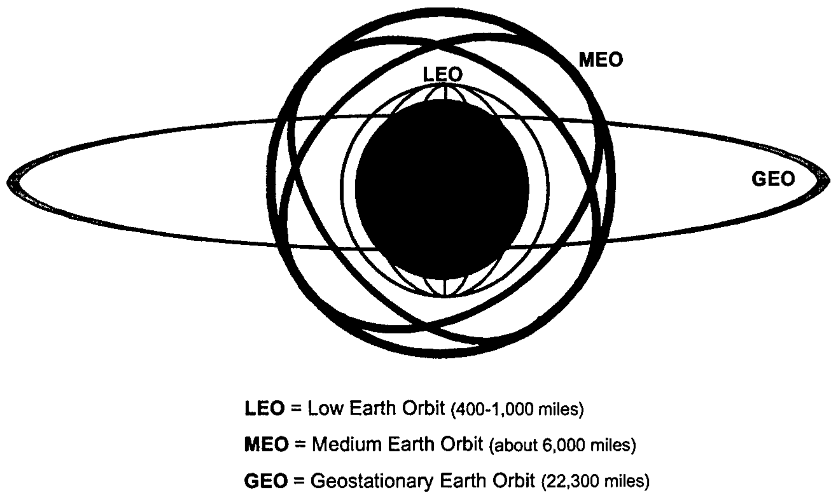

Figure 1. Classification of Orbits[5]

international partnerships. This aids the systems in gaining "landing rights" for their signals in countries around the world.[6]

As noted above, the majority of the projected commercial satellite systems will provide communications. These satellite systems can be divided into three types: mobile voice and data, direct broadcast, and broadband communications. Mobile voice and data are generally low data rate systems which provide services to a small handheld user terminal, such as a pager or a mobile phone. Direct broadcast systems send wide bandwidths of data, generally video, in a single direction and have small transportable receive-only antennas which can be used to receive hundreds of commercial channels. These systems are currently marketed with names such as DirecTV, Primestar, and Echostar. Broadband communications provide two-way high bandwidth trunks to support high volume, interactive voice and data communications. In addition to these three types of communication services, commercial satellites systems are also expanding into remote sensing systems. By examining the architectures of systems in these four categories—mobile voice and data; direct broadcast; broadband; and remote sensing—additional insight into the impact of the system architecture on capabilities can be gained.

Mobile Voice and Data Communications

Several mobile voice and data systems are near completion. Orbcomm, Iridium, and Globalstar provide three examples which illustrate how different satellite architectures lead to different capabilities for the user.

ORBCOMM

Orbcomm began limited operations in 1995 and currently has 12 satellites in a low earth orbit with plans to expand to a total of 36 satellites by 1999. These satellites will provide worldwide coverage (excluding the north and south pole). The Orbcomm system is analogous to the US postal service—also called a "store and forward" type of service. Orbcomm checks each customer terminal for voice mail or data messages to send as it passes overhead and delivers messages it has received for the customer. One of Orbcomm's areas of specialization is remote monitoring.[7] A sensor is placed with a mobile asset—such as an airplane, truck, or ship—and is pulsed each time the satellite passes for an update of the asset's location. Thus assets can be tracked inexpensively over large areas worldwide.

Orbcomm provides an inexpensive worldwide method of communications. It provides same day reliable delivery, but is not designed for real-time or interactive communications as delivery time is measured in hours, not seconds. Thus while it can enhance situational awareness with routine data traffic and periodic status updates, it is unsuitable for real-time control of forces engaged in battle.

GLOBALSTAR

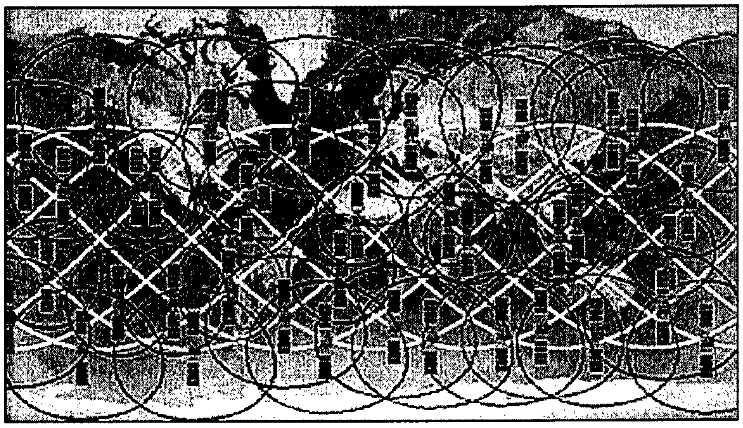

Figure 2. Orbital Paths and Coverage provided by Globalstar Constellation[8]

Globalstar is another low earth orbiting satellite system providing mobile voice and kilo-bit-per-second data services. It provides continuous coverage worldwide with 48 satellites and will begin operations in 1998.[9] It was designed for use with mobile phones, but could also be used for any service which operates over a phone line such as facsimile.

The Globalstar architecture works as a relay system.[10] When a call is placed from a mobile phone or terminal, it connects to Globalstar's local communications gateway. From the Globalstar gateway, the call is sent out via the public switched network to its destination. It closely resembles a cellular phone system with the cell sites located in satellites instead of ground antennas. Thus it is well-suited for a regional communications system if there is a local gateway. This satellite system supports mobility with good voice quality and could support encrypted communications by employing a secure DOD communications gateway.[11]

IRIDIUM

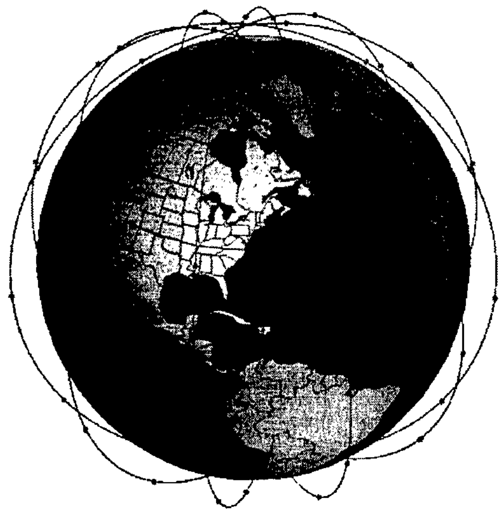

Figure 3. Iridium Constellation[12]

Iridium is designed to provide mobile voice and data. Its satellites, unlike Orbcomm and Globalstar, are in a polar orbit and can communicate with each other via cross-links. In addition to being state-of-the-art, this architecture provides some major advantages. First of all, there is virtually nowhere on the globe—even at the poles—which does not receive continuous coverage. This can be a factor for some forces, such as the submarine forces, which may occasionally travel in extreme northern regions. Secondly, a call to the United States can be placed from anywhere and bypass all foreign infrastructure. Thus, unless the enemy can intercept the call as it is placed or intercept it in the United States, the call is inaccessible. There are no in-theater communications gateways to be monitored or destroyed. This also means there are no associated in-theater support requirements except for spare user terminals/mobile phones. The constellation and cross-linking also provide some impressive survivability within the communications system. An Air Force Institute of Technology modeling study of

Iridium concluded that the constellation could lose 36 of its 66 satellites and still deliver data in an average of less than 200 milliseconds.[13]

Iridium is an excellent choice for a first-in communications system to use anywhere in the world on a moment's notice. However, it is not a covert system and should be combined with encryption devices for secure (unmonitored) communications.[14] It provides timely access throughout the world with a great deal of robustness and thus makes an outstanding global voice and low data-rate communications system.

Direct Broadcast

Direct broadcast systems generally use geostationary satellites to cover fixed regions. They provide high power unidirectional (one-way) broadcasts. These broadcasts can carry hundreds of television channels, other video, voice, or data. Return signals, such as requests, are sent via other means. The military currently is acquiring the Global Broadcast Service, which will provide worldwide coverage using direct broadcast technology.[15] The Global Broadcast Service will be used to enable geographic Commanders-in-Chief (CINCs) to provide a common view of the battlespace to their forces. This communications capability, combined with sensors and status of forces updates, will enable the type of situational awareness envisioned in *Joint Vision 2010.*

Broadband Communications

High bandwidth systems are a bit farther out on the horizon, post 2000. Two of the most exciting are Teledesic and Celestri, which both plan operations beginning in 2002.[16]

TELEDESIC and CELESTRI

Teledesic, backed by Microsoft's Bill Gates and McCaw Cellular's Craig McCaw, is billed as the "internet in the sky."[17] The concept is to provide a communications system which will provide interconnection speeds and bandwidth comparable to fiber optics so that systems and software designed for use on land-based systems will be able to be used and extended to remote areas via satellite. The satellites, currently projected to number 288, will enable gigabits of bandwidth to connect to any location on the globe, including polar locations. Celestri uses a combination of low earth orbiting and geosynchronous satellites to provide similar high bandwidth multimedia services. Like Iridium, Teledesic and Celestri satellites will have cross-links and adaptive routing algorithms to ensure data travels by the fastest route through the net of satellites and is downlinked to a communications gateway in the vicinity of the end-user. The capabilities of Teledesic or Celestri will enable the military, if it so desires, to satisfy all of its current communications needs using a single system.[18] While dependence on a single system is inadvisable, by itself either of these systems would provide an enormous capability for the military to enhance its vision of global "plug and play" communications with a minimal logistical tail.

Remote Sensing

In addition to communications, commercial satellites are expanding into remote sensing systems such as imagery, positioning, and weather. The French Satellite pour L'Observation de la Terre (SPOT) and the US LandSat corporations have been providing imagery to commercial customers for years.[19] Several corporations have launched earth imaging and remote sensing systems such as OrbView, Space Imaging Satellite

(CRSS/SIS), and Earlybird. These systems are planned to have two to eight satellites each and provide regional or worldwide coverage with access several times per day.

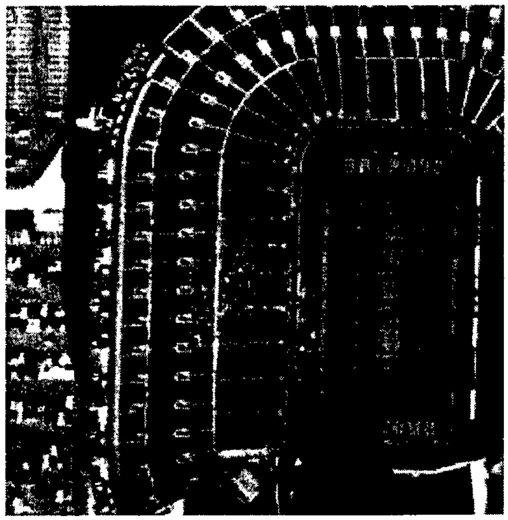

Figure 4. Satellite Image of Denver Broncos stadium with one meter resolution taken by IKONOS Space Imaging Satellite.[20]

In the future, intelligence specialists may be able to answer General Schwarzkopf's famous question "How deep is the sand?" without ever setting foot in the desert by using commercially available data. These systems provide the opportunity of readily available unclassified intelligence which could be used for planning, rehearsal, and coordination.[21]

Summary

Together the emerging commercial systems offer the potential of a powerful market-driven system of systems. For routine messages and updates on status of forces, systems like Orbcomm provide a effective and affordable worldwide capability. Global voice and data communications to handheld terminals is available from Iridium in a robust architecture. Multimedia broadcast updates using the Global Broadcast Service provide situational awareness for forces via a portable one meter antenna. High bandwidth interactive communications, through systems like Teledesic and Celestri, could connect a deployed base communications system into the public switched network and support distributed, collaborative planning. Remote sensing is another area where industry offers systems to augment or replace customized military capabilities. Trade-offs in cost, resolution, timeliness, and coverage are made possible by the rapid growth in commercial systems able to address these requirements in an unclassified manner.

In the past commercial satellite systems offered only point-to-point communications. As a result, a customized infrastructure of services which were unique to the military was developed and commercial satellite communications were used to augment this infrastructure.[22] In the next few years, commercial satellites will be offering greatly expanded services such as mobile voice and data, broadcast, broadband communications, and remote sensing. These services have the mobility, coverage, and interoperability needed to achieve the military's vision of command and control for the future.

Notes

[1]Marco A. Caceres, *World Space Systems Briefing*, (Fairfax, Va.: Teal Group, May 1996), GEOSTATIONARY Commercial Communications Satellites Market Overview 1-9, LEO/MEO Commercial Communications Satellites Market Overview 1-6.

[2]A table of emerging commercial satellite systems is provided in Appendix B.

[3]For more information on satellite terms and concepts, refer to Appendix A.

[4]Examples include Boeing (Teledesic); Lockheed Martin (many geostationary); Space Systems/Loral (Globalstar + many geostationary); Orbital Sciences (Orbcomm & OrbView); Hughes (ICO + many geostationary); Motorola (Iridium + Celestri); and TRW (Odyssey). Reference Federal Aviation Administration, *LEO Commercial Market Projections*, 25 July 1997, 2-4.

[5]Source for information shown in figure is William J. Cook, "1997 A New Space Odyssey." *U.S. News & World Report*, 3 March 1997, 52. Geostationary satellites maintain a geosynchronous orbit at the equator. Geostationary satellites not only rotate at the same pace as the earth (geosynchronous), but they also remain relatively fixed in latitude relative to the earth.

[6]For a more in-depth explanation of the term "landing rights," see Appendix A.

[7]Anton B. Reut and Todd Hara, "Remote Monitoring of Military Assets using Commercial LEO Satellites," (Dulles, Va.: Orbcomm, 1995), 4; and Orbcomm "Simply Everywhere" series of marketing pamphlets.

[8]Source for figure is Globalstar at http://www.globalstar.com/img/system.sat2.gif.

Notes

[9]Rich Henderson and Kent Penwarden, "Globalstar for the Military," (San Jose, Calif.: Globalstar, 1995), 2.

[10]Naval Security Group, *Project Starcross Phase 1 Report,* September 1996, D-5.

[11]The procurement of a secure Globalstar gateway was studied by DISA in 1997 and 1998, but a contract was not awarded.

[12]Source for figure is the University of Minnesota Geometry Center at http://www.geom.umn.edu/~worfolk/savi/images/iridium_big.gif.

[13]Douglas Stenger, "Survivability Analysis of the Iridium Low Earth Orbit Satellite Network," (Dayton, Ohio: AFIT, Jun 96), abstract. In contrast, if a geostationary satellite serving an area is destroyed, its service to that area is completely lost.

[14] DISA has contracted for modifications and infrastructure to enable use of STU-III compatible communications with Iridium. NSA's CONDOR program is developing the technology for mobile phone encryption capability; refer to NSA Information Systems Security Organization Web Site at http://www.nsa.gov:8080/programs/missi/condor.html.

[15]See Appendix C for additional information on the Global Broadcast Service.

[16]Teledesic web site; on-line, Internet, February 1998, available from http://www.teledesic.com/overview.html. Celestri Web Site, on-line, Internet, February 1998, available from http://www.mot.com/GSS/SSTG/projects/celestri.

[17] Teledesic web site; on-line, Internet, February 1998, available from http://www.teledesic.com/overview.html.

[18] In order for these systems to meet military communications needs, the DOD must communicate its requirements during system design and be prepared to fund those modifications which are military-unique. Without proactive action by the government, these systems will provide only those capabilities driven by commercial needs.

[19]William Dunn, "Skycams Drain Floods, Save Lives, Sell Burgers," *American Demographics*, July 1992, 22.

[20] Source for picture is Space Imaging at http://www.spaceimage.com/home/gifs/prod_samp/datasheets/orighigh/1P_broncos.jpg.

[21]Time between customer order and product delivery for newly acquired, high priority image generally ranges between two to seven days. Reference Jonathan Ball, "Satellite Remote Sensing," on-line, Internet, 11 March 1998, available from http://www.comlinks.com/satcom/srsintro.htm, 5.

[22]Michael J. Muolo, *Space Handbook: A Warfighter's Guide to Space,* vol. 1 (Maxwell AFB, Ala.: Air University Press, 1993), 73-147. One notable exception to the DOD's custom architecture was the military's use of SPOT for imagery.

Chapter 3

Command & Control

The effectiveness of C2 ultimately depends upon the human commander at the heart of every C2 process and system.

—Thomas P. Coakley

Command is relatively well understood as the exercise of authority and responsibility over forces.[1] Control monitors and imposes limits on the forces in how far they can go in accomplishing their mission.[2] The phrase "command and control" brings to mind the leadership of people, as well as sophisticated computer systems and organizational processes.[3] The *Concept for Future Joint Operations* defines C2 as "the means by which the Joint Force Commander synchronizes activities in time, space, and purpose to achieve unity of effort."[4]

One of the best known theories on command and control today is Col John Boyd's OODA loop.[5] He divided the command and control process into four steps: observe-orient-decide-act (OODA). The process is continuous as new information is constantly entering in the observe step and thus can be depicted as a cycle or "OODA loop." Col Boyd recommended gaining an advantage over adversaries by executing this loop of command and control faster than they can.[6] This means that by the time an enemy has made a decision, the conditions on which that decision was based have already changed.

The result of this advantage in the speed of command and control is to keep the enemy off-balance and uncertain of the true condition of the battlefield.

Another way to achieve this effect is through parallel warfare. In parallel warfare, the enemy is attacked in so many vital areas that he cannot react to his condition and is paralyzed.[7] In both Col Boyd's approach to command and control warfare and in parallel warfare, two key ingredients are the situational awareness on which decisions are based and the ability to rapidly execute decisions.

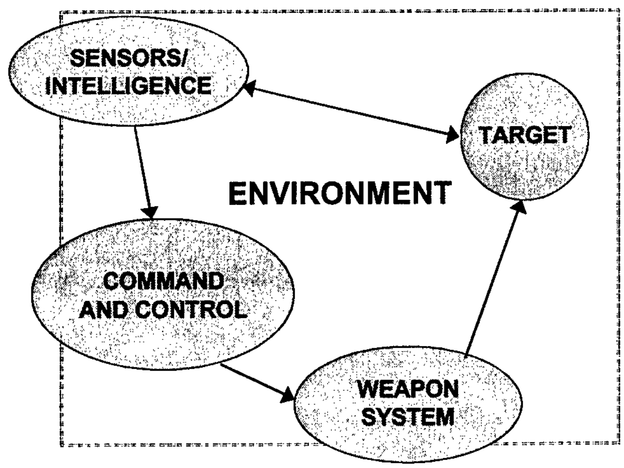

Figure 5. System of Systems

Adm William Owens, in his introduction to *Dominant Battlespace Knowledge*, postulated an emerging US system of systems with three components: intelligence, command and control, and precision force.[8] With this emerging system of systems, "our growing capacity to transfer dominant battlespace knowledge to all our forces, coupled with real-time awareness of the status of all our forces and the understanding of what they can do with their growing capacity to apply force with speed, accuracy, and precision, builds the realm of "near perfect" mission allocation."[9] Commercial satellite systems can collect intelligence through remote sensing systems, transfer information to forces with direct broadcast technology, coordinate planning with broadband multimedia systems, and apply force through mobile voice and data communications. These capabilities can have a profound impact on joint operations.

The Impact on Joint Operations

Joint Vision 2010 predicts, "Individual war fighters will be empowered as never before, with an array of detection, targeting, and communications equipment that will greatly magnify the power of small units. Strategically, this improvement will enable more rapid power projection and reduced logistics tail." The greater availability of up-to-date information will undoubtedly impact joint operations. The consequences of having the ability to communicate at more places with greater capacity and greater mobility will change some aspects of command and control. It will also leave the fundamental aspects of command in war, such as the need for individual judgement and initiative, unchanged.

Availability of Information

Information will be available to more people, on a faster timeline, in greater quantities, and to a greater level of detail. The Joint Broadcast Service is already having an impact on joint operations in Bosnia. Predator Unmanned Airborne Vehicle (UAV) video is shown at HQ European Command, the Combined Air Operations Center, the Joint Analysis Center, and the brigades in theater at the same time. Carrier Battle Group Commanders, once isolated from other authorities, are now connected electronically to forces ashore and in the continental US. Large map files of gigabit size, once deliverable only by hardcopy or more recently on CD-ROM, take minutes to send over the new direct broadcast systems and will take only seconds to send over future broadband gigabit-per-second systems. Current intelligence, once available only through highly classified systems, is available commercially and can be used in unclassified mission planning systems. In the future, communications and data will be relatively available and affordable—it is the analysts, the staffs, and the decision-makers who are the key nodes.

The key to managing the vast amount of information available will be organization. Many people have cable or direct broadcast television, which sends megabits-per second of information direct to their home continuously. But they are not overwhelmed with information because they know how to access what is relevant and how to ignore what is not. The Internet provides access to unimaginable amounts of information, but with an intelligent search engine, a user can quickly find information of interest even if he has no idea where to look for it. Thus a key element of command and control will continue to be determining what information is relevant and, of increasing importance, what information is irrelevant. Automated ways of organizing and displaying information are essential to ensuring information is enlightening rather than overwhelming.[10]

Ubiquity and Mobility of Communications

Not only will more information be available, but the military will be able to share information with forces in places and a timeframe not previously possible. With the pre-deployed infrastructure of commercial satellites, the military can take advantage of pay-as-you-go communications anywhere on the globe. These communications will provide a wide range of standard services with portable terminals and on-the-move connectivity for dispersed forces enabling cross-cueing of targeting information and real-time information exchange with weapon platforms.

The opportunity presented by technology is to increase the audience of information. "Situational Awareness," "Dominant Battlespace Knowledge," or the "Common Operational Picture" are three expressions for the concept of providing a baseline of information to a broad base of forces so that forces can become more coordinated and synchronized in the execution of their mission. One advantage is, with knowledge of the situation at multiple echelons, lower level organizations can anticipate requests and have a better understanding of how their plans and actions support the overall campaign. As stated by Frank Snyder in *Command and Control*,

> At all levels prudent commanders try to anticipate likely situations, think them through, and create plans to deal with them; problems that have not been thought through in advance are less likely to be solved effectively under the pressure of a rapidly evolving situation.[11]

Thus the improved situational awareness enable each unit to be more effective in ensuring battlespace dominance.

Changes in Organization

Organizations will need to adapt to take advantage of the technologies being developed and deployed.[12] As more information is shared between the echelons of command, organizational structures will flatten to facilitate the flow of information and decisions.[13] As stated by the Defense Science Board:

> As the battlefield becomes more digitized, the systems more automated, and—especially—as battle becomes more dispersed (a centuries-old trend), an overriding requirement on both the commander and the technical architecture is to maintain, and strengthen, human relationships, mutual support and the mutual understanding on which it is based, laterally and in both directions in the command structure...We believe the future technology *enables* and future battle *demands*, a wider and more diverse set of command relationships.[14]

Decision-making, to fully exploit the potential of increased information, must become more decentralized. As stated in *War in the Information Age*, "Many decisions will be decentralized. Of those decision-making processes that remain centralized, most will be structured in a participative way; fewer decisions will be made by a single leader or manager."[15] This implies not only the need for a greater flow of information, but the ability to conduct distributed collaborative planning and decision-making.

Need for Judgement

Commercial satellite services, with the emerging systems planned, can greatly facilitate command and control, especially for deployed forces. They cannot, however, replace the human judgement needed to motivate people and draw the relevant ideas from a mountain of information. As stated in *Joint Vision 2010*, "...our success will depend, as it has historically, upon the physical, intellectual, and moral strengths of the individual."[16] In examining the promise of technology, it is wise to remember that the human element remains critical to the success of any endeavor. Technology has its limitations and vulnerabilities, as well as its benefits and efficiencies.

The warning brought by technology is not to rely on it to the extent that you do not realize it shortcomings. Sensors can be tricked; communications can be manipulated; processors can produce illogical results.[17] Decision-makers must remain flexible and should not become so over-awed by technology that they fail to use their judgement.[18] The use of technology to enhance command and control must be balanced by the recognition of the enduring role of judgement and initiative in human endeavors—including war.

Joint Vision 2010 Operational Concepts

In the *Concept for Future Joint Operations: Expanding Joint Vision 2010*, command and control is recognized as "perhaps the single most important function" for joint operations in the information age with Information Superiority as the key enabler.[19] "Optimum C2 in the 2010 environment will depend on seamless communications, all-weather real-time sensors, current and accurate databases, and the resulting near-real-time situational awareness for the JFC and the entire chain of command."[20]

In *Joint Vision 2010,* four operational concepts provide the backbone for our future war fighting capability: Dominant Maneuver, Precision Engagement, Full-Dimension Protection, and Focused Logistics, with Information Superiority as a key enabler. For Dominant Maneuver, "information superiority will allow information-based control to displace physical control of forces…this will promote seamless integration of both forces and capabilities while limiting the potential for fratricide."[21] For Precision Engagement, "information superiority provides the means to rapidly and accurately identify and assess targets or objectives and to select and apply the precise force to achieve the desired effects."[2223] "Full Dimension Protection requires information superiority to provide battlespace awareness in all dimensions." Finally, in Focused Logistics the information processing systems for the integrated logistics system of 2010 "will be an integral part of the commander's command and control system."[24]

> Future commanders will use the Information Age's revolutionary advances in information transfer, storage, recognition, and filtering to orchestrate attacks and defenses. Theater-wide taskings will flow with unprecedented fidelity and speed. Commanders will convert "the understanding of the battlespace into missions and assignments designed to alter, control, and dominate that space.[25]

Command and control will evolve, pulled by the articulated vision of the future and pushed by the capabilities of new technology. Enhanced battlespace awareness, enabled by the use of direct broadcast technologies for distribution and remote sensing systems for unclassified terrain information, will provide a better knowledge at all echelons of command of both friendly and enemy situations. Distributed collaborative technologies, supported by global broadband communications will enable a reduction in forward staffs with greater support for collaborative planning and decision-making between different locations. Global mobile communications will enable updating forces on-the-move with changes in the situation and tasking updates. Emerging commercial satellite systems provide the worldwide flexibility for the military to achieve the underlying infrastructure needed to make this vision of the future a reality.

Notes

[1] John F. Schmitt, "A Concept for Marine Corps Command and Control," *Science of Command and Control: Part III, Coping with Change,* (Fairfax, Virg.: AFCEA International Press, 1995), 13.

[2] Thomas P. Coakley, *Command and Control for War and Peace,* (Washington D.C.: National Defense University Press, January 1992), 38.

[3] Kenneth Moll, as quoted in Gregory A. Roman, *The Command or Control Dilemma,* (Maxwell AFB, Ala.: Air University Press, February 1997), 1.

[4] *Concept for Future Joint Operations: Expanding Joint Vision 2010,* (Ft Monroe, Va.: Joint Warfighting Center, May 1997), 65.

[5] John R. Boyd, "Organic Design for Command and Control" (unpublished papers, Air University, May 1987), 23. Discussed in *Concept for Future Joint Operations: Expanding Joint Vision 2010* (67), Air Force literature, and Army and Marine Corps doctrine (*MCDP 6*, 63).

[6] Ibid., 23. John Boyd states, "A similar implicit orientation for commanders and subordinates alike will allow them to diminish their friction and reduce time, thereby permit them to exploit variety/rapidity while maintaining harmony/initiative, thereby permit them to get inside the adversary's O-O-D-A loops, thereby magnify adversary's friction and stretch-out his time, thereby deny adversary the opportunity to cope with events/efforts as they unfold."

[7] Jeffery R. Barnett, *Future War: An Assessment of Aerospace Campaigns in 2010,* (Maxwell AFB, Ala.: Air University Press, January 1996), xxi.

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[8] Adm William A. Owens, *Dominant Battlespace Knowledge,* (Washington D.C.: National Defense University, April 1996), 1.

[9] Ibid., 2.

[10] David Alberts, "The Future of Command and Control with Dominant Battlespace Knowledge," *Dominant Battlespace Knowledge,* (Washington, D.C.: National Defense University, April 1996), 76.

[11] Frank M. Snyder, *Command and Control: The Literature and Commentaries,* (Washington D.C.: National Defense University Press, September 1993), 29.

[12] *New World Vistas: Air and Space Power for the 21st Century*, (Washington, D.C.: USAF Scientific Advisory Board,1995), Information Technology Volume, 12.

[13] David Alberts, 88; and remarks attributed to Gen. John Sheehan by Charlotte Adams, "Has US C3I Technology Gone Too Far?'Asks Top US Commander," *Military & Aerospace Electronics*, Vol. 7, Issue 10 (October 1996): 9.

[14] *Defense Science Board 1996 Summer Study Task Force on Tactics and Technology for the 21st Century,* (Washington D.C.: Office of the Secretary of Defense, October 1996) V12-V14.

[15] Gordon R. Sullivan, and James M. Dubik, *War in the Information Age*, (Carlisle Barracks, Pa.: Air War College, 6 June 1994), 9.

[16] *Joint Vision 2010*, 19.

[17] This was highlighted in MCDP 6, Operation VERBAL IMAGE.

[18] Thomas P. Coakley, 74.

[19] *Concept for Future Joint Operations: Expanding Joint Vision 2010*, 65.

[20] Ibid., 66.

[21] Ibid., 50.

[22] Ibid., 52.

[23] Ibid., 53.

[24] Ibid., 54.

[25] Adm. William A. Owens, "The Emerging System of Systems," *Proceedings*, May 1995, 38.

Chapter 4

Considerations

> *(1) Information Systems are helpful only to the extent that they reduce the fog of war, and (2) The command structure must be capable of winning even after the computer dies.*
>
> —Kenneth Allard

The new capabilities brought by commercial satellites systems also bring new dependencies. Concerns about assured access, security, and leveling of the playing field must be examined if the military is to use these systems for command and control purposes. These concerns become increasingly important as the future military comes to depend heavily on command and control to achieve the synchronized efforts which give dispersed forces mass.

Assured Access

Assured access means that a connection exists between the user and a network and when a user picks up the phone, the dial tone is there. The loss of assured access can be due to a lack of connectivity; traffic overload, such as commonly experienced with the public switched network on Mother's Day; or to the loss of a key node. Many military systems overcome their lack of capacity by providing *flash* communications priority to assure access for critical transmissions. In a system with surge capacity for peak loads and/or with a diversity of means available, assured access can be provided without such a priority system. While commercial systems are not hardened per se, they generally incorporate a tremendous robustness through redundant infrastructure. Within their network architecture, commercial systems provide redundancy for critical nodes and alternate routing for failed paths, leading to a robust and reliable system. An example of this was demonstrated in a study of Iridium.[1] In addition, the rapidly growing competitive field for commercial satellite systems provides many alternate sources for equivalent functionality.

Despite the immensity of the projected commercial infrastructure after the deployments of systems such as Teledesic and Celestri, there are still threats, such as a high-altitude electromagnetic pulse, which could seriously disrupt commercial and military communications systems.[2] Thus hardened military communications systems, such as the Military Strategic and Tactical Relay (MILSTAR), are needed to meet certain military requirements.[3]

Could an adversary deny the US military the use of a commercial satellite system? Many of the commercial satellites systems being planned and fielded today are managed by multinational corporations. If the US military was engaged in an activity which was not supported by member nations, could these multinational corporations deny the use of their system? For example, Iridium is managed by a consortium with members from China, Africa, Canada, India, Saudi Arabia, Venezuela, Brazil, Russia, South Korea, Japan, Taiwan, Italy, Thailand, Germany, and the United States.[4] While it might be possible to deny service, it is highly unlikely that a multinational corporation would choose to do so to a member nation and a paying customer.[5] First of all, and a bottom line for corporations, it is bad for business. This tactic is made even less likely by the substantial presence and influence of US members in most of these corporations.[6] None-the-less, as a measure of prudence, it makes sense to confine military communications to the majority of satellite systems, which have significant US ownership and oversight.

Security

Security can take a number of forms. Encryption secures the content of a transmission. Physical security protects the system infrastructure from attack. Protected user account databases and operational security of organizational charts and directories protects user identity. Firewalls and monitoring devices protect systems from hacking and spoofing. Spread spectrum signals and directional antennas can assist users in avoiding detection.

Since an adversary may depend on the same commercial systems, it can be more advantageous for them to exploit the US military's use of a system—vice damaging a system—by monitoring traffic, disrupting operations, and perhaps even manipulating traffic by sending false data. Thus, military commanders need to know where communications are vulnerable. With information warfare defensive operations, we can protect the authenticity and accuracy of the communications being conducted. The networks with satellite cross-linking provide a clear advantage in protection because the infrastructure and the content of the communications are not readily accessible.[7] In contrast, any phone call which travels the public switched telecommunications network is vulnerable to monitoring, exploitation, and disruption.

Security capabilities and features will depend on the specifics of the system and its implementation including the system architecture, formats, and configuration. The military needs to be proactive in stating its requirements and in seeking commercial satellite systems which have architectures and services which provide advantage to the US military. By modifying these systems to incorporate military-unique requirements, the government can increase the utility of these systems to their operations.[8] Enhanced security is a common modification to commercial systems to enhance military utility.

Operations Security

In addition to protecting the content of traffic with encryption, the military often protects the location of the parties involved in communications and the timing of their communications. These operational security aspects go beyond encryption of the data and are usually only required for sensitive communications. Airborne transmissions, such as satellite communications have a disadvantage in that they provide a means for locating the caller. The commercial antennas used for mobile communications are generally omni-directional antennas—that is antennas that radiate well in all directions—so transmissions from these devices can be intercepted from any direction with line-of-sight to the terminal. With multiple interceptors, the location of the user can be approximated.

One method to discourage location, and also to minimize the effects of interference, is to use spread spectrum technology. This technology hides the signal over a wide portion of the spectrum so that it becomes virtually indistinguishable from regular spectrum noise. Code Division Multiple Access (CDMA) waveforms use spread spectrum techniques to minimize interference between signals and to efficiently use the allocated spectrum. Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) are other waveforms in common use. Instead of spreading the signal, they use time or frequency slots to share the spectrum between multiple users.

The result is a more concentrated signal which is easier to locate and jam. The only sure way to prevent detection is to not use a communications device; but spread spectrum technology (e.g. CDMA) minimizes the signature of the signal and makes detection and location more difficult.[9]

Leveling of the Playing Field

Generally, commercial systems are available to anyone with money. Any worldwide capability which is available to the United States commercially is also available to an adversary. This results in a concern over the potential leveling of the playing field in the arena of command and control when using commercial systems. Jeffery Cooper in *Dominant Battlespace Knowledge* states:

> Because dominant battlespace knowledge is largely built from commercial systems, it is available to others. Whether or not the technology itself gives the United States an advantage will depend on who uses it well...Whether we can harvest this revolution and strengthen our national security is a matter of choice; so is the selection of focus and means of implementation, which, in turn, depends less on enhancing the individual piece-parts than on integrating all elements into a synergistic, effective organization.[10]

By failing to leverage commercial capabilities, the US military may not be leveling the playing field; it may be turning the playing field in favor of an adversary. While part of the value of communications is in the attributes of the asset itself, the majority of its utility is derived from how well it is used. One reason why the military shifted from service-provided communications systems to joint systems was, despite lots of communication capabilities, not all personnel who needed to communicate in joint operations could communicate.[11] Thus, military program managers need to focus on the integration and interoperability of future command and control systems, as well as capabilities.

Interoperability

The commercial market is driven by consumers to adapt to interfaces and protocols already in place. If a new capability requires too much additional expense or too different an interface to be "user-friendly," the capability is difficult to market. In contrast, many military systems require extensive training to ensure proper use. All commercial voice communications systems currently offered or planned are interoperable through the public switched telecommunications network.[12] For example, regardless of what mobile phone or which long-distance service a person has, they can call Mom. For data, the internet is spurring the growth of new ways to access data of numerous formats. Commercial products, because of economic realities, provide user-friendly capabilities to access their data via commonly used formats.[13]

Potential Modifications to Commercial Systems

Commercial systems have progressed significantly in providing capabilities which were once of interest only to the military. Much of this is due to the fact that businesses and individuals have become much more expeditionary in nature. Twenty years ago, only the military was interested in going to the remote corners of the world to set up operations; today it is the dream of many multi-national corporations to develop new markets worldwide. Businessmen carry pagers and mobile phones to cities in every continent and track assets on land, sea, and in the air. From a communications perspective, many of the military and commercial needs are converging and, thus, many of the capabilities for mobility, coverage, capacity, and interoperability, once only required by the military, are now directly available to consumers.

Encryption, though used by the financial world and increasingly by the business world, remains a US government-provided capability for the military.[14] Since security is an essential part of military operations, it is necessary to incorporate encryption in systems used for command and control purposes. The modification of commercial systems to add encryption is greatly facilitated by new information format standards such as the Personal Computer Memory Card International Association (PCMCIA) standardized card. The current plan is that this credit card-sized device will have a common interface sleeve, which can be integrated into mobile phones, faxes, computers, and other communications devices to enable encryption and authentication.[15] Other potential modifications include ruggedization and transportability of the user terminal.

Historically, the acquisition process has made it very difficult to present the war fighter the ability to make trades between cost, performance, and schedule once the requirement has been approved. Now, with the ability to conduct Advanced Concept Technology Demonstrations, program managers have a way to enable the user to "test-drive" a preliminary capability.[16] This "test-drive" can facilitate the discussion on what is required and what is feasible with current technology.[17]

Summary

Commercial satellite systems, in order to meet the requirements of consumers, have been built to provide robust services. Depending on the system architecture, considerable ability to withstand damage and sustain operations can exist. Assured access is also enhanced by the growing number of systems that provide equivalent services. These systems, however, can be readily vulnerable in a nuclear environment. Hardened systems, such as MILSTAR, are needed for operations at the high-intensity end of the conflict spectrum. Thus, a baseline of military command and control capabilities, augmented by a variety of commercial satellite services, is recommended.[18]

The security of a commercial satellite system is dependent on the specifics of the system and its implementation. Features such as cross-linking potentially enhance the security of the system by reducing the accessibility of communications. Spread spectrum waveforms, such as CDMA, can minimize interference and hinder detection of the user. With modifications to support encryption, commercial systems can be used for secure communications.

Commercial satellite systems are also driven by the consumer market to provide services which are interoperable. Commercial communications interconnect via the immense infrastructure of the public switched telecommunications network; data services link via the internet. Commercial satellite services cannot meet the requirements for military command and control in all situations. They can, however, provide assured access throughout the world in most environments, operate securely with modifications to support encryption, and provide a basis for interoperability. Thus commercial satellite systems, as a globally pre-deployed infrastructure, could be used to enhance the military's ability to command and control joint operations.

Notes

[1] Douglas Stenger, abstract.

[2] A high-altitude electromagnetic pulse is caused by a nuclear detonation in the stratosphere. The electromagnetic shock waves which result would degrade and may render inoperable electronic equipment in the vicinity. Radiation hardening of satellites is one way to mitigate nuclear effects. Since radiation hardening affects the selection of

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components throughout the satellite, it must be designed in from the start and can greatly increase the cost and weight of a satellite.

[3] Michael J. Muolo, 145. Based on the high intensity scenario, a baseline of core command and control systems will need to be hardened. However, a large portion of the supporting intelligence and communications requirements can be met with less than radiation-hardened systems.

[4] *Iridium Today* (Washington, D.C.: Iridium, Winter 1995), 28.

[5] In Iridium, for example, the consortium which manages the system does not have the capability to deny service. Motorola, which operates the system for Iridium, is the only member capable of denying service. It is improbable that Motorola would deny service unless there was a violation of international law.

[6] Federal Aviation Administration, 2-4.

[7] Michael Lars, "The Price of the Deal," *Newsweek*, 9 December 1996, 44.

[8] The government will generally bear the cost of these modifications, which can run in the tens of millions of dollars. However, the military can leverage billions of dollars of commercial investment. The cost-benefit trade needs to be examined for the capabilities to be provided, but the increase in utility can be significant.

[9] David A. Brown, "Government Efforts Confound Commercial Wireless Security," *Signal* 52. no. 7 (March 1998): 68.

[10] Jeffery Cooper, "DBK and Future Warfare," *Dominant Battlespace Knowledge*, (Washington D.C.: National Defense University, April 1996), 102.

[11] In Grenada, for example, there was difficulty in coordinating operations between the Army and the Air Force.

[12] This does not mean that each handsets can be used with any system or that the different constellations of satellites can interoperate. Here, interoperability denotes that the functionality can be shared between the different systems—e.g. I can use my Iridium phone to call you on your Globalstar phone (or any other of the commercial phones).

[13] An example of the accessibility of data is the use on the internet of the hypertext mark-up language (*.html) which enables web surfers to view data created by a number of different applications.

[14] Though commercial encryption is becoming available, the military is required by DOD Directives to use National Security Agency-approved encryption devices.

[15] "PC Card Standard Overview," on-line, Internet, 11 March 1998, available from http://beta.missilab.com/readertest/standard.html.

[16] For more information on ideas to do this, please reference Mark R. Ashpole, "Leveraging the Commercial Satellite Business," (Maxwell AFB, Ala.: Air University, March 1998).

[17] One example of early user interaction was the use of Qualcomm handsets to demonstrate Globalstar's capability for the CONDOR Program in summer 1996 and on-going. For more information see http://www.nsa.gov:8080/programs/missi/condor.html. Exercises, such the Joint Warfighter Interoperability Demonstrations, and the work of the battle labs can also help facilitate these discussions.

[18] While radiation hardening is one military-unique which is hard to incorporate without major system modifications, many other requirements can be incorporated into

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commercial satellite systems if the discussions with the vendor are started early in the design process.

Chapter 5

Conclusions

> *...regardless of how sophisticated technology becomes, the warfighter's judgement, creativity, and adaptability in the face of highly dynamic situations will be essential to the success of future joint operations.*
>
> —Joint Vision 2010

Commercial satellite systems will be providing capabilities in the next few years which can enable commanders to achieve the vision proposed for the year 2010. The ability to track organizations, vehicles, and even people becomes possible with the type of remote asset monitoring provided by Orbcomm and others. Highly mobile communications become available anywhere in the world at a moment's notice with minimal set-up and at an affordable cost through systems such as Iridium, Teledesic, and Celestri. Interoperability rests on commercial standards, which are driven by the need to remain compatible with the enormous investments already made in the public switched telecommunications network and in the Internet. Commercial remote sensing systems can provide unclassified intelligence for mission planning in a coalition environment.

The systems being fielded in the next few years have greatly improved mobility, coverage, and capacity and can provide interoperability and assured access; these capabilities are essential for command and control of an expeditionary force. Dominant Maneuver made possible by ubiquitous mobile communications; Precision Engagement through real-time situational awareness facilitated by direct broadcast and wideband technologies available globally; Full Dimensional Protection enabled by cohesive command and control of dispersed forces; and Focused Logistics with improved support to a rapidly changing environment.

With these capabilities, the explosion in information available to all echelons of command can be expected to continue to accelerate. With the tremendous pre-deployed infrastructure provided by commercial satellite systems, responsive support for command and control can be greatly enhanced. These systems increase the collection of data available globally; they provide a means of delivering this and other information worldwide; and they provide a means for distributed communications, planning, and execution using the information. Together they make the vision of dominant battlespace knowledge achievable.

Recommendations for Commanders

Commanders need to appreciate the balance between the human element and technology to achieve the command and control vision of the future. Command and control systems need to be judged by whether they integrate the organization, internally and externally, in a seamless fashion. This means demanding systems that enable all parts of the organization to communicate. This means pushing for the integration of information into relevant systems so that the transfer of data is automatic and timely. Integration costs money; but with the focus on joint operations, communicators need to be pressed to find solutions which already exist on a DOD-wide scale instead of band-aiding the local process with local initiatives.[1]

Commanders need to understand their systems' architectures so that they can take advantage of capabilities.[2] Even more important than the capabilities, commanders need to understand their systems' vulnerabilities. If a commander relies on a system for the command and control of his forces, he has to know how the system can be deceived, manipulated, or destroyed.[3] This will help him in overcoming any awe of its capabilities and give him a basis for understanding when the information provided needs to be re-verified or is misleading.

Finally, commanders should not assume military-unique systems are more capable than commercial systems. That may have been the case in some days past, but is not necessarily true today.[4] The ability of the commercial consumer to push industry to develop friendly interoperable systems with mission-enhancing features is considerable. In many areas, but particularly in interoperability, commercial communications systems surpass military systems.[5]

Recommendations for the Program Manager

Traditionally, the military has acquired custom systems to provide command and control. This has resulted in very capable and generally unstandardized systems that were difficult to learn and limited in interoperability. To the extent the military can leverage commercial technology, it provides a basis for interoperability.[6] Using commercial systems is one of the most direct ways to leverage commercial technology.[7]

There still remain a few military requirements which commercial services will not offer as standard features in the near term. Encryption with National Security Agency (NSA)-approved algorithms remains a US government-unique requirement. The impact and cost of integrating encryption depends on the early identification of data format and physical interface requirements for the encryption device. The standardization on devices such as the PCMCIA card should enable vendors of commercial communications of all types to incorporate encryption-compatible designs.[8] Many other requirements can be met with military versions of the end user devices, such as ruggedized or water-sealed handsets or directional, low probability of intercept antennas. For requirements such as radiation-hardened satellites, either the government will need to take a deliberate role in spurring the development and fielding of these capabilities as part of commercial systems or it will need to continue to procure custom systems to satisfy these requirements.[9]

Program Managers need to begin the dialogue with the user on requirements early.[10] Advanced Concept Technology Demonstrations can assist the requirements process by providing an awareness of current capabilities and a basis for discussions between the acquirer, users, and industry. Acquisitions should be structured to maintain a DOD-wide perspective on interoperability and should leverage the commercial infrastructure by supporting standard interfaces.

Summary

For the command and control of joint forces envisioned in *Joint Vision 2010* and its *Concept for Future Joint Operations*, commercial satellite systems can fulfill many of the requirements with few modifications. With a handheld phone and a PCMCIA-based card, forces will be able to access anyone with a phone or STU-III worldwide—truly an advance in mobility, access, and interoperability. [11] For a resource-constrained military driven to draw out force modernization, the leverage provided by exploiting commercial-off-the-shelf systems is compelling. The military, once the principal expeditionary organization, can now benefit from the explosion in business as a multinational presence.

Notes

[1] An example of a DOD-wide program which enhances command and control is the Global Command and Control System (GCCS). More information about GCCS can be found at http://www.disa.mil/d2/gccs.

[2] Their technical personnel understand the communication and sensor systems' abilities or should be directed to learn them. Many times, systems have capabilities which are never used because no one but the technical staff knows they exist and because operational staffs are too involved in day-to-day operations to learn.

[3] This recommendation is echoed by Sue B. Carter in "A Shot to the Space Brain," (Maxwell AFB, Ala.: Air University, March 1997), 56.

[4] General Howell M. Estes, "Space—Expanding the Acquisition Envelope," address to the Air Force Association 1997 Acquisition Update Symposium, 22 May 1997, available on the internet at http://www.spacecom.af.mil/usspace/speech5.htm. John A. Alic et al, *Beyond Spinoff,* (Boston, Mass.: Harvard Business School Press, 1992), 7-8. Military expertise is quickly shifting from being the lead in all aspects of satellites to being the lead only in military unique aspects.

[5] Because of the numerous unique formats such as Tactical Digital Information Link (TADIL)-A, -B, -C, and –J formats, many war fighters still cannot communicate with each other. Despite incompatibilities and proprietary technology in commercial communications systems, they are interconnected via gateways to the public switched telecommunications network and/or internet.

[6] The Defense Messaging System (DMS), which is the follow-on to AUTODIN, is based on the commercial X.400 and X.500 standards to enhance interoperability. Current message systems are a patchwork of 45 different email applications and have encountered problems with interoperability. Reference DMS Web Site, available from http://www.disa.mil/D2/dms/docs/progovw.

[7] Incorporating commercial standards into requirements where appropriate can also facilitate interoperability between systems. In the proposal evaluation process, proprietary interfaces can pose a risk to system interoperability and should be noted.

[8]Emmett Paige, Jr., Assistant Secretary of Defense (Command, Control, Communications and Intelligence), memorandum to Military Departments, Defense Agencies, DOD Field Activities, and Joint Staff with attachment, subject: DOD Personal Computer Policy Implementation Plan FY1995 – FY2000, 7 April 1995.

[9] For more ideas on acquisition approaches to leverage commercial technology, please reference Mark R. Ashpole, "Leveraging the Commercial Satellite Business," (Maxwell AFB, Ala.: Air University, March 1998).

[10] For commercial satellite systems, I recommend beginning discussions on military requirements with vendors once the Federal Communications Commission (FCC) request for spectrum has been filed.

[11] DISA/D216, "Mobile Satellite Service (MSS) Fact Sheet for Preparation of Inputs to the FY98 Program Objective Memorandum," undated.

Appendix A

Satellite Terms and Concepts

Orbits

Geostationary (GEO) satellites orbit at the same relative pace as the surface of the earth (one orbit per 24 hours, altitude of 35,800 kilometers) in an equatorial plane and thus appear to a ground observer to be fixed in space. Thus, geostationary satellites have the advantage of always being overhead in the same place. **Low earth orbit (LEO)** and **medium earth orbit (MEO)** satellites have orbits which are closer to the earth and which move in and out of the view of a user on the surface of the earth. LEO satellites range in altitude from 400 to 2,000 kilometers (km) and require minimal radiation hardening to protect them from the space environment. MEO satellites orbit in altitudes around 10,000 km and generally incorporate more hardening due to the closeness of the Van Allen belts. To provide continuous coverage over one place in the earth with LEO or MEO systems, multiple satellites are needed and the system must be intelligent enough to pass a user from one satellite to the next as they move overhead. This has the disadvantage of adding cost and complexity to the satellite system, but also reduces the signal delay in transmission due to the shorter distance between the user and the satellite and enables a single system to provide greater coverage of the earth's surface. It also reduces the signal path loss, requiring smaller, less expensive ground equipment.

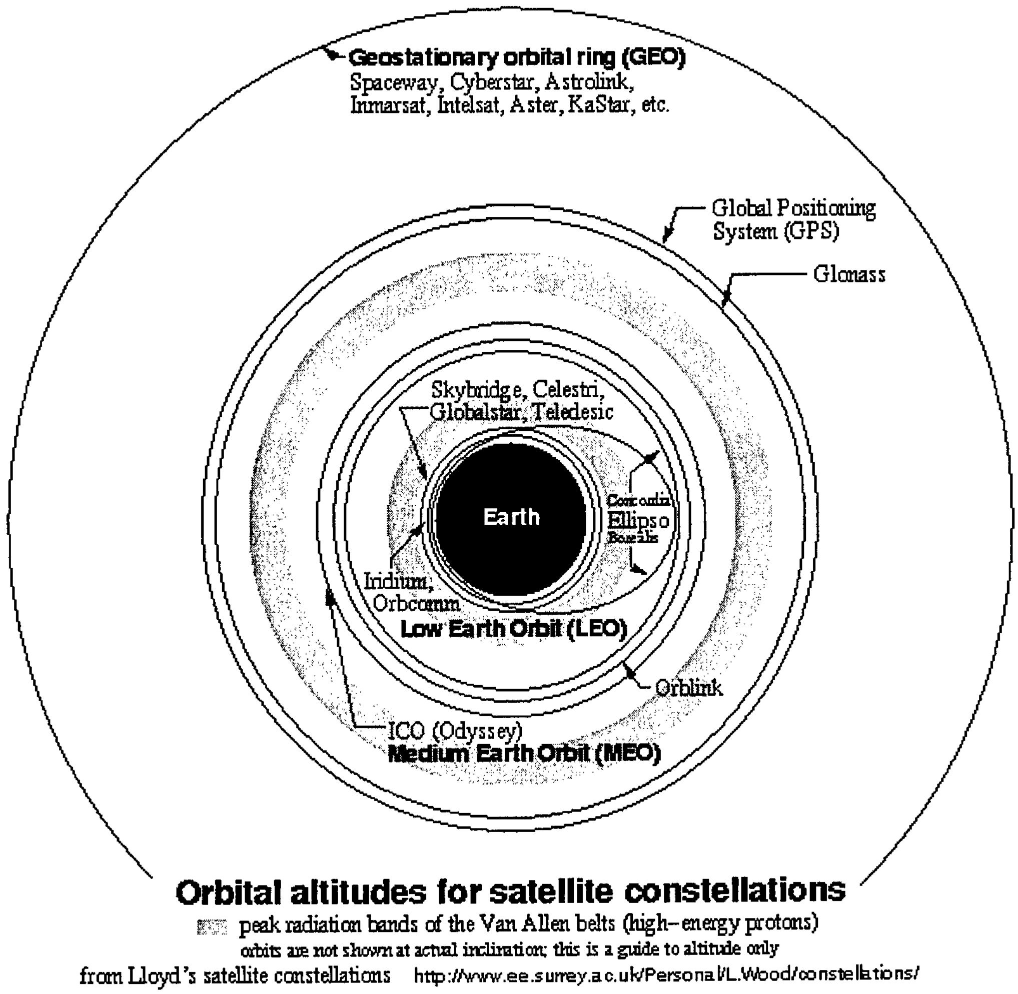

Figure 6. Types of Orbits

Coverage, footprint, and field of view all refer to the area of the earth with line-of-sight to the satellite. The higher the altitude of the satellite, the greater the field of view each satellite has. Since LEO satellites are closer to the earth, they "see" less of the earth at any given time, and constellations require more satellites to provide worldwide coverage. The coverage is usually shown with concentric circles for various elevation angles (0 degrees is the edge of the field of view). The higher the elevation angle, generally the stronger the signal. Depending on the signal strength and the satellite beamwidth, an elevation angle of at least 10-20 and as much as 40 degrees may be necessary to ensure good communications. At very low elevation angles, the signal is weaker and may be blocked by trees or buildings. Worldwide coverage is used here to denote coverage between 65 degrees north latitude and 65 degrees south latitude around the globe. Global coverage is used to denote coverage between 90 degrees north latitude and at least 65 degrees south latitude around the globe.

Telecommunications Terms

Broadband refers to the size of the communications channel. The "broader" the channel, the more capacity it has. A **narrowband** circuit generally handles a single voice or low rate data connection, e.g. 2400 bits-per-second. Broadband circuits can carry numerous connections and are suitable for connecting phones and/or data switches and for transmitting large amounts of data, such as needed for video-teleconferencing. **Multimedia** refers to the capability of a circuit to handle voice, data, and video traffic. **Landing rights**: By international convention, a signal may be broadcast within the licensed spectrum, but the right to receive the signal and to transmit from any country's airspace must also be licensed with the country. In many cases, a premium is paid for these licenses. For many new consumer-oriented commercial systems, a usage fee has been the agreement of choice—e.g. for each $3 phone call, the host nation receives 5 cents.[1] This approach has enabled the system owners to rapidly gain approval for marketing and use of their system in a large number of countries.[2]

Notes

[1] *Iridium Today*, Winter 1995, 25.
[2] Based on discussions with representatives of Iridium and Globalstar in 1996.

Appendix B

Summary of Emerging Commercial Satellite Systems

Table 1. Overview of Planned Satellite Systems with Worldwide Coverage[1]

System Name	**Initial Ops**	**Est. Cost**	**Constel-lation**	**Company(s)**	**Services**
Astrolink	2000	$4B	9 GEO	Lockheed-Martin	broadband data
Celestri	2001-2	$12.9B	63 LEO; 9 GEO	Motorola	broadband multimedia
CRSS/SIS	1998		2	Space Imaging EOSAT	imagery
EarlyBird	1997		3	Ball Arospace, Earth Watch	imagery
FAIsat	2002	$250M	26 LEO	Final Analysis, Polyot	messaging
GE Starsys **(cancelled)**	1999	$170M	24 LEO	GE AmeriCom, C.L.S. N America	messaging
GEMNet	1999	$160M	38 LEO	Orbital Sciences	tracking, e-mail, paging
Globalstar	1999	$2.6B	48 LEO (4 up)	Loral, Qualcomm & others	mobile voice, data, paging
ICO	2000	$2.6B	10 MEO	British Telecom, Hughes & others	mobile voice, data, paging
Inmarsat-3 *P Horizons*	now *2002*	$690M *$2B*	5 GEO 3-4 GEO	Int'l signatories	mobile voice & data *Mobile broadband data*
Iridium	Sep 98	$4.4B	66 LEO (51 up)	Motorola, Nippon & others	mobile voice, data, paging
M-Star	2002	$6.1B	72 LEO	Motorola	broadband data
Odyssey **(cancelled)**	2001	$3.2B	12 MEO	TRW, Teleglobe	mobile voice & data
Orbcomm	now-98	$350M	36 LEO (10 up)	Orbital Sciences, Teleglobe	messaging, email, & positioning
OrbView	now-		4 (2 up)	Orbital Sciences	Imagery and weather
QuickBird	1998		2	Ball Aerospace, Earth Watch	imagery

Table 1 (Continued)

System Name	Initial Ops	Est. Cost	Constel-lation	Company(s)	Services
Skybridge	2001-2	$3.5B	64 LEO	Alcatel Espace, Loral & others	broadband multimedia
Teledesic	2002	$9B	288 LEO	Boeing	broadband multimedia
VITAsat	Sep 97-	$10M	2 LEO (1 up)	Volunteers in Tech Assistance, Final Analysis	email & data

Notes

[1] Table was compiled from various sources. Primary source was the satellite communications database in the Analysys web site available from http://www.analysys.com/products/satellite/database.htm. Secondary source was article by Jonathan Ball, "Satellite Remote Sensing," on-line, Internet, 11 March 1998, available from http://www.comlinks.com/satcom/srsintro.htm.

Appendix C

Global Broadcast Service

Global Broadcast Service (GBS) Phase 1

Phase 1 of GBS provides a commercial-off-the-shelf based system for concept of operations development. A prototype system, the Joint Broadcast Service is currently providing coverage to Bosnia as well as sites in Europe and is being used operationally.[1] It provides weather, news, maps, US Secret and NATO imagery, Defense Intelligence and Joint Staff briefings, and theater-collected Unmanned Airborne Vehicle (UAV) imagery to thirty sites including the Joint Analysis Center, HQ US European Command, the Combined Air Operations Center, Task Force Eagle, and several Army Brigades. The prototype system provides a 30 mega-bits-per-second broadcast. A similar system, the Global Broadcast Service (GBS) Testbed provides a 30 mega-bits per second broadcast to units in CONUS to support the development of a GBS concept of operations. Together, the GBS Testbed and the Joint Broadcast Service are the Phase 1 of the Global Broadcast Service.

Global Broadcast Service (GBS) Phase 2

Phase 2 of the Global Broadcast Service will provide 96 mega-bits-per-second of broadcast into each of the Pacific, Atlantic, and Indian Ocean regions.[2] Phase 2, which was awarded in Nov 97, will provide a direct broadcast payload on three of the UHF Follow-On (UFO) satellites. UFO-8 covers the pacific region (San Diego to Japan), UFO 9 covers the Atlantic (Washington D.C. to Germany) and UFO-10 will cover the Indian Ocean (Germany to Korea).

Global Broadcast Service (GBS) Phase 3

Phase 3 of GBS is referred to as "the objective system" and will be the replacement for GBS Phase 2. Its architecture and capabilities have not yet been determined.

Notes

[1] Bob Brewin, S12.
[2] Mega-bits per second = 1,000,000 bits per second.

Glossary

ACSC	Air Command and Staff College
ACTD	Advanced Concept Technology Demonstration
Adm	Admiral
AFCEA	Air Force Communications Electronics Association
AFIT	Air Force Institute of Technology
ATO	Air Tasking Order
AU	Air University
AWACS	Airborne Warning and Control System
AWC	Air War College
Brig Gen	Brigadier General, US Air Force
C2	Command and Control
C3I	Command, Control, Communications & Intelligence
CAOC	Combined Air Operations Center
CDMA	Code Division Multiple Access
CD-ROM	Compressed Disk-Read Only Memory
CIA	Central Intelligence Agency
CINC	Commander in Chief
CNN	Cable News Network
Col	Colonel, US Air Force
CONOPs	Concept of Operations
CONUS	Continental United States
CPT	Captain, US Army
CRSS	Commercial Remote Sensing Satellite
DBK	Dominant Battlespace Knowledge
DIA	Defense Intelligence Agency
DMS	Defense Messaging System
DOD	Department of Defense
EROS	Earth Remote Observation System
EUCOM	European Command
FDMA	Frequency Division Multiple Access
GBS	Global Broadcast Service
GCCS	Global Command and Control System

GEO	Geostationary
HQ	Headquarters
JAC	Joint Analysis Center
JBS	Joint Broadcast Service
JFACC	Joint Force Air Component Commander
JFC	Joint Force Commander
JSF	Joint Strike Fighter
LEO	Low Earth Orbit
Maj	Major, US Air Force
MANPAD	Man-Portable Air Defense System
MEO	Medium Earth Orbit
MILSTAR	Military Strategic and Tactical Relay
MNC	Multinational Corporation
NATO	North Atlantic Treaty Organization
NIMA	National Imagery and Mapping Agency
NSA	National Security Agency
OODA	Observe-Orient-Decide-Act
OSD	Office of the Secretary of Defense
PCMCIA	Personal Computer Memory Card International Association
PGM	Precision-Guided Munition
Raptors	Nickname for the F-22 Fighter
SATCOM	Satellite Communications
SIS	Space Imaging Satellite
SPOT	Satellite pour L'Observation de la Terre
TADIL	Tactical Digital Information Link
TDMA	Time Division Multiple Access
UAV	Unmanned Airborne Vehicle
UFO	UHF Follow-On (military satellite program)
UHF	Ultra-High Frequency
US	United States
USAF	United States Air Force
USEUCOM	US European Command
VITA	Volunteers in Technical Assistance

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