Big Blue Arrows: Lines of Information and the Transformation Force

A Monograph

by

Major Kenneth E. Viall

United States Army

School of Advanced Military Studies

United States Army Command and General Staff College

Fort Leavenworth, Kansas

First Term AY 00-01

REPORT DOCUMENTATION PAGE

1. REPORT DATE (DD-MM-YYYY) 01-02-2001	2. REPORT TYPE monograph	3. DATES COVERED (FROM - TO) xx-08-2000 to xx-02-2001
4. TITLE AND SUBTITLE Big Blue Arrows: Lines of Information and the Transformation Force Unclassified		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Viall, Kenneth E. ;		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Command & General Staff College School of Advanced Military Studies 1 Reynolds Ave. Fort Leavenworth , KS 66027		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS ,		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT A PUBLIC RELEASE ,		
13. SUPPLEMENTARY NOTES		

14. ABSTRACT

The monograph examines the friendly information system portion of the battlefield superiority dilemma. It focuses on a very specific portion of operational campaign design: the ?Big Blue Arrow,? a metaphor for decisive operations requiring the movement of forces to achieve objectives. Since future forces expect information superiority, the monograph seeks to determine whether future transformation forces can apply the lessons of history to better focus information support during operational maneuver. The analysis uses a conceptual model of bases and lines of information based on the writings of Jomini and early Signal Corps doctrine. The study reviews the impact of the telegraph, radio, and computer on operational maneuver from the Civil War to modern conflicts such as Operation Desert Storm and Operation Uphold Democracy. The analysis focuses on fundamental characteristics of responsiveness, mobility, survivability, and sustainability of information systems during movement. The monograph concludes that future forces must plan lines of information to focus support where most needed. Without discipline, military information networks tend to overload weak links at the expense of important information. Although satellite communications and digital computer networks provide great capabilities for transformation forces, fundamental constraints still exist in line-of-sight radio propagation, communications channel capacity, and network congestion.

15. SUBJECT TERMS

military information networks; Civil War; Operation Desert Storm; Operation Uphold Democracy

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
			Same as Report (SAR)	72	Burgess, Ed burgesse@leavenworth.army.mil
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 913 758-3171 DSN 585-3171

SCHOOL OF ADVANCED MILITARY STUDIES

MONOGRAPH APPROVAL

Major Kenneth E. Viall

Title of Monograph: Big Blue Arrows: Lines of Information and the Transformation Force

Approved by:

____, Monograph Director
COL Patrick Shaha, M.S.

____, Director, School of Advanced Military Studies
COL Robin P. Swan, MMAS

____, Director, Graduate Degree Programs
Philip J. Brookes, Ph.D.

Accepted this 23d day of May 2001 by:

Abstract

Big Blue Arrows: Lines of Information and the Transformation Force, by Major Kenneth E. Viall, 74 pages.

The monograph examines the friendly information system portion of the battlefield superiority dilemma. It focuses on a very specific portion of operational campaign design: the "Big Blue Arrow," a metaphor for decisive operations requiring the movement of forces to achieve objectives. Since future forces expect information superiority, the monograph seeks to determine whether future transformation forces can apply the lessons of history to better focus information support during operational maneuver.

The analysis uses a conceptual model of bases and lines of information based on the writings of Jomini and early Signal Corps doctrine. The study reviews the impact of the telegraph, radio, and computer on operational maneuver from the Civil War to modern conflicts such as Operation Desert Storm and Operation Uphold Democracy. The analysis focuses on fundamental characteristics of responsiveness, mobility, survivability, and sustainability of information systems during movement.

The monograph concludes that future forces must plan lines of information to focus support where most needed. Without discipline, military information networks tend to overload weak links at the expense of important information. Although satellite communications and digital computer networks provide great capabilities for transformation forces, fundamental constraints still exist in line-of-sight radio propagation, communications channel capacity, and network congestion.

TABLE OF CONTENTS

Chapter One

Lines of Information for Military Operations

Introduction

The term "information" in the modern military sense evokes mental images of advanced satellite communications systems, computer networks, cyber-warfare, and advanced intelligence and target acquisition capabilities. However, the fundamental problem of harnessing information in support of military endeavors has challenged military organizations for generations. Military information systems, unlike most civilian counterparts, must have the capabilities to quickly install and operate in complex and unfavorable terrain; provide secure, survivable, and reliable service; and react flexibly to support friendly force maneuvers.[1]

The monograph examines the friendly information system portion of the battlefield superiority dilemma by focusing on a very specific portion of operational campaign design: decisive operations requiring the movement of forces away from supporting bases to achieve objectives. The "Big Blue Arrow" represents a simple metaphor for the operational maneuver of friendly forces.[2] New doctrinal concepts of rapid, simultaneous fire and maneuver for the transition forces dramatically increase the challenge for providing information requisite to maintain situational awareness.[3] Movement negates some of the benefits information systems accrue from stability and the passage of time. Can Army transformation forces effectively apply the lessons of history to better focus information support during operational maneuver?

[1] Michael Ryan and Michael Frater, *A Tactical Communications Systems for Future Land Warfare*, Working Paper 109 ed. (Australia: Land Warfare Studies Centre, 2000), 4.

[2] Big Blue Arrow —"big" representing tactical to operational level, "blue" representing friendly forces, "arrow" showing the operational maneuver which represents in most cases the decisive operation of a phase. The concept generated from observations of Command and General Staff College students at Fort Leavenworth during the academic year 1999.

[3] Michael Mehaffy, "Vanguard of the Objective Force," *Military Review* 80, no. 5 (September-October 2000): 10.

Background

Before the implementation of the telegraph for military usage, long-range command and control of military organizations relied either on couriers to transfer information or confronted the limits of visual line-of-sight range with combinations of relay stations using signal flags, mirrors, or other visual signs.[4] As the 19th Century brought advances in communications technology, the military incorporated innovations including telegraphs, telephones, and wireless radios to gain an information advantage. Other pioneers sought ways to protect friendly military communications, and targeted enemy capabilities in ways unprecedented in warfare. The technological spiral of developments in advanced computers and network technologies has become central to debate on the true value of modern information technology in support of military operations.

Looking forward, Joint Vision 2020 and Army vision statements stress the importance of information superiority for the conduct of future warfare.[5] Secretary of Defense Cohen described one outcome of the 1997 Quadrennial Defense Review as a challenge to the Army to "accelerate its Force XXI modernization plan, which will revolutionize combat capability by enhancing battlefield awareness through modern information technology."[6] Even Army Field Manual 3-0, Operations, includes information as an element of combat power that "enhances leadership and magnifies the effects of maneuver, firepower, and protection."[7]

In 1915, Brigadier General George Scriven, Chief Signal Officer of the Army, captured the essence of military information service by noting that

> . . . if a commander's service of information is better than that of his adversary he possesses a wider knowledge and superior control; he selects with certainty his objective and arrives at it first; he perceives weakness before his own is discovered or strength

[4] Martin L. Van Creveld, *Command in war* (Cambridge, Mass: Harvard University Press, 1985), 27.

[5] Joint Chiefs of Staff, *Joint Vision 2020* [Online] (Joint Staff, 2000, accessed November 3, 2000); available from http://www.dtic.mil/jv2020/jv2020a.pdf. See also Eric K. Shinseki, *The Army vision: Soldiers on Point for the Nation . . . Persuasive in Peace, Invincible in War* [Online] (1999, accessed 12 October 1999); available from www.hqda.army.mil/OCSA/vision.htm.

[6] William S. Cohen, "Report of the Quadrennial Defense Review," *Joint Force Quarterly*, no. 16 (1997): 11 Force XXI design includes the "digitization" of the battlefield with network technology embedded in weapons systems and organizations.

[7] Headquarters Department of the Army, *Operations (DRAG Edition)*, Field Manual 3-0 (Washington, DC: U.S. Government Printing Office, 2000), 4-9.

> before his weakness is known; he anticipates movements, alters dispositions, executes plans unknown to the enemy; in short, the successful soldier commands the situation by force of superior knowledge, and never is it more true than in war that knowledge is power.[8]

The attributes of effective information that Scriven described remain relevant today. In *War and Anti-War*, Alvin and Heidi Toffler reduce the military's challenge to the imperative to "acquire, process, distribute, and protect information."[9] Recent military actions have highlighted the increasing reliance on information during operations. The impact of automation and computer networks now extends beyond the traditional, hierarchical command and control paradigm to also provide a crucial and more inclusive distributed information flow. Accordingly, some futurists and Defense Department panels envision the concept of "Network-Centric Warfare" based on the real-time joint application of combat power acquired through "information systems and enhanced capacities of network-centric computing which link disparate platforms and systems for synergistic effect."[10]

Despite euphoria over the promise of information technology, military visionaries retain a healthy skepticism over creating an over-reliance on technology. At critical times during the deployment and employment of military forces, especially during initial occupation of a new base of operations after movement, information demands have sometime exceeded capacities despite the advances in communications technology.[11] While some writers seem quick to declare that information technology heralds a "Revolution of Military Affairs," others advise the military to "not believe that new concepts or capabilities will negate the fundamental nature of war. Friction together with fog, ambiguity, chance, and uncertainty will dominate future battlefields as it has in the past . . . although technology is important, it is only a tool."[12]

---

[8] George Percival Scriven, *The service of information, United States Army*, Circular, no. 8 (Washington, DC: Govt. print. off., 1915).

[9] Alvin Toffler and Heidi Toffler, *War and anti-war : survival at the dawn of the 21st century* (Boston: Little Brown, 1993; Reprint Warner Books, 1995).

[10] David S. Alberts, John J. Gartska, and Frederick P. Stein, *Network Centric Warfare: Developing and Leveraging Information Superiority* (Washington, DC: C4ISR Cooperative Research Program, 1999), 86. Richard Lee Armitage, Andrew F. Krepinevich, and Others, "National Security in the 21st Century: The Challenge of Transformation," *Joint Force Quarterly*, no. 16 (1997): 18.

[11] Van Creveld, 258.

[12] Williamson Murray, "Thinking About Revolutions in Military Affairs," *Joint Force Quarterly*,

Big Blue Arrows

In his book *In Pursuit of Military Excellence,* Shimon Naveh traces the development of operational art in the Soviet, German, and United States militaries. He notes the peculiar negative side-effect of German reliance on technology first under Moltke and then Schlieffen.

> The real value of the modern means of communication eluded Schlieffen and his school . . . the telegraph, telephone and radio provided the magic agent which was supposed to make their visionary system of command work. . . . Hence, the communication illusion, which was generated by the devices technology provided, created a deceptive faith in an absolute, centralized but effective mode of command. It encouraged the military leadership to ignore the factor of randomness and the principle of inner-system cognitive tension, and to repress the healthy penchant for tactical initiative.[13]

The optimistic view holds that modern information technologies "synthesized by operational art and new organizational concepts, present an opportunity for discontinuous change—a great leap in warfighting—from the industrial to information age."[14] However, if the synthesis of capabilities, concepts, and operational art is flawed, Naveh's "communication illusion" could easily become an "information illusion"—a "deceptive faith" that future forces can rely on technology to guarantee that accurate information will be available when most needed in the conduct of operations.

Joint doctrine defines information superiority as "the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same."[15] As information technology develops, it seems increasingly difficult to determine when a state of relative information superiority exists, and even more challenging to prevent friendly information systems from becoming a critical vulnerability. A cognitive tension exists today between the technologists who see the power of information technology transforming society, and the military theorists who doubt the efficacy of the same concepts to transform the

---

no. 16 (1997): 76.

[13] Shimon Naveh, *In pursuit of military excellence : the evolution of operational theory*, The Cummings Center series . 7. (London ; Portland, OR: Frank Cass, 1997), 59.

[14] Lawrence E. Casper, Irving L. Halter, and others, "Knowledge Based Warfare: A Security Strategy for the Next Century," *Joint Force Quarterly*, no. 13 (1996): 82.

[15] Joint Chiefs of Staff, *Information Operations*., Joint Publication 3-13 (Washington D.C.: U.S. Government Printing Office, 1996).

military. How can military forces first conceptualize information superiority,and then organize and operate within a reasonable paradigm to ensure the success of military operations in the future? Any operational concept for information superiority must not only seek the proper application of information as an element of combat power, but also be firmly based in the fundamental nature of war.

Lines of Information

Having established a doctrinal framework to define a useful construct for information during operational maneuver, discussion of the construct proceeds with the battlefield framework first articulated by Jomini and now accepted in joint doctrine. During operational maneuver, commanders recognize limitations to movement caused by factors such as logistics and relative combat power. Commanders consequently select bases of operations, lines of communications, and lines of operations to ensure the military force has adequate operational reach. Military theory and writings on information as early as 1915 considered the "ordinary lines of information of a division under the three conditions of the camp, the march, and contact with the enemy…."[16] The fundamental concept of "lines of information" presents an operational way to view information as an element of combat power.

Based on a simple concept of bases and lines of information, three levels of information technology offer benefits to maneuver: the speed of wire and radio connectivity, the range and capacity of satellites and electronic systems, and the synergy of all in the form of digital computer networks. In the late nineteenth to early twentieth centuries, simple linear electrical connectivity provided by telegraph, telephone, and early radio augmented existing physical means of information transfer. Individual military personnel served as the information processors in the different echelons of command. Later, electronic radios proliferated throughout military echelons and long-range satellite communications provided operational agility beginning with the Vietnam

[16] Scriven, 33.

War. Over the last decade, digital communications networks, including computer networks, have become become the prevalent information conduits.

Research Design

Ideal criteria for evaluating lines of information exist in joint doctrine for command and control: information systems must be interoperable, flexible, responsive, mobile, disciplined, survivable, and sustainable.[17] Interoperability, discipline, and flexibility are factors more critical to the initial design, control, and management of information systems and less relevant to the line of information. The remaining principles—responsiveness, mobility, survivability, and sustainability—provide criteria for evaluation of lines of information across the three technological levels (radio and wire, satellite and computer, and digital networks).

First, did historical information systems effectively adapt the fundamentals of courier, telegraphy, and radio to support operational maneuver from the Civil War to Korea? Second, did the systems effectively adapt to long-range communications and more mobile and efficient tactical communications? Finally, did information systems effectively adapt to digital networking technology and the proliferation of computers on the battlefield? The answers to these three questions, applied to the expectations of the transformation forces, determine if such forces will be able to effectively leverage information systems during operational maneuver in the future.

The relevance of the research topic to the military today reflects the cognitive tension between technology in society and the application of technology in the uncertain environment of war. The challenge to future warriors is to reap the benefit of technology while understanding the limitations that

> Information superiority neither equates to perfect information, nor does it mean the elimination of the fog of war. Information systems, processes, and operations add their own sources of friction and fog to the operational environment.[18]

---

[17] Joint Chiefs of Staff, *Doctrine for Command, Control, Communications, and Computer (C4) Systems Support to Joint Operations*, Joint Publication 6-0 (Washington D.C.: U.S. Government Printing Office, 1995), II-4. See the appendix for a comparison of criteria.

[18] Joint Chiefs of Staff, *Joint Vision 2010* (Washington, DC: Department of Defense, 1997), 9.

The reality of future physical and environmental constraints may dictate that networks expected to link the entire theater will actually become localized phenomena. Pockets of information will be virtually connected via various communications media to other information pockets within the theater, forming lines of information between bases of operations and forces in motion. Operational understanding of the line of information could be an essential element in providing focus for the application of information resources and in recognizing the impact of information on operational reach.

Chapter Two

In Search of a Digital Napoleon

Jomini and Battlefield Geometry

In his book *Summary of the Art of War,* Antoine Henri-Jomini outlined a strategic framework for the conduct of war. Jomini recognized a spatial relationship between maneuver forces and terrain and his framework included bases of operations, lines of operation, and lines of communication to link a force's movement from bases to successive decisive points.[19] Army operational doctrine embraces many of Jomini's concepts as current elements of operational design.[20] Certain aspects of this framework are relevant to effectively leverage information systems during operational maneuver.

Battlefield organization consists of the arrangement of forces in purpose, time, and space to accomplish a mission. Decisive operations are those that "directly achieve the mission of the higher headquarters."[21] There can be only one decisive operation for any phase and level of headquarters. For offensive and defensive combat missions, the most likely decisive operation involves ground force maneuver. Simultaneous shaping operations "at any echelon create and preserve conditions for the success of the decisive operation."[22] Sustaining operations generate and maintain combat power. Throughout all planning, designation of a "main effort" provides a conceptual focal point to guide execution and set priorities for shaping and sustaining operations.

Bases of operations provide secure places for force concentration "from which the army obtains its reinforcements and resources, from which it starts when it takes to the offensive, to which it retreats when necessary, and by which it is supported when it takes position to cover the country defensively."[23] Today's equivalent strategic bases are located in the United States and, to

---

[19] C. Kenneth Allard, *Command, control, and the common defense* (New Haven: Yale University Press, 1990), 48. See also Antoine Henri Jomini, *Jomini and his Summary of the art of war*, trans. J.D Hittle, Roots of Strategy, vol. 2, (Mechanicsburg, PA: Stackpole Books, 1987), 472.
[20] Headquarters Department of the Army, 5-6.
[21] Ibid.
[22] Ibid., 4-22.
[23] Jomini, 465.

a lesser extent, at major troop concentrations garrisoned overseas in friendly countries such as Germany and South Korea. Military operations requiring the overseas projection of land power will require the establishment of operational bases with sufficient infrastructure to support the concentration of troops before decisive operations can begin.

Commanders apply operational art using concepts such as centers of gravity, decisive points, and objectives to define their operational aim for a particular phase of a campaign. The aim helps provide the line of operation along which maneuver forces will move to achieve their objectives. The default aim of the initial deployment to the theater of operations often equates to the successful closure of sufficient combat power to conduct operations. Subsequent aims reflect discrete steps toward the accomplishment of the force's mission.

Zones and lines of operation provide a linkage between bases of operations and selected objectives. Jomini differentiated between interior lines and exterior lines of operations. Interior lines provided a positional advantage, security and, when confronted by multiple opponents, the flexibility to reposition forces using shorter lines of operation. However, an agile enemy could negate the handicap of exterior lines--interior lines would not always provide a decisive advantage.[24]

Lines of communication consist of the "practical routes connecting different portions of the army."[25] The line of communication supports sustaining operations of logistical units between bases and forces on the march. Commodities such as fuel and ammunition remain critical to maintaining momentum. The culminating point of an operation is reached at a "point in time and space where the attacker's effective combat power no longer exceeds that of the defender's, or the attacker's momentum is no longer sustainable."[26] Operational reach considers such culmination and provides the commander with a measure of the "distance over which military power can be employed decisively."[27]

---

[24] Headquarters Department of the Army, 5-9.
[25] Jomini, 473.
[26] Headquarters Department of the Army, 5-10.
[27] Ibid.

Jomini in the Information Age

Jomini based his theories on the campaigns of Napoleon. Napoleon used trusted aides as information conduits for "collecting specific information on the fighting condition of the Grand Armée, gathering intelligence, and assisting in the control of forces in battle."[28] His command interest in his own information system reflects the modern belief that

> A tactical unit may be seen as an information-processing machine: in order for an officer to control such a unit, a tactical formation must be capable of transmitting among its ranks the commands issued from above, and to communicate back to the officer the results of implementing his commands…[it] must be part of the C3 network…it is a rather simple matter to understand how such a network functioned in peacetime. What is not so simple is to picture the conditions under which such a machine can prevent disintegration during battle. How can a complex machine maintain itself in the middle of turmoil? [29]

Napoleon perhaps viewed his aides as responsive, mobile, survivable, and sustainable—they represented his personal solution to the turmoil of battle. Despite great advances in technology, personal liaison still remains one of the most powerful tools, and

> informal communications and decision making channels will remain as valid in the 21st century as in the past. In an age when our command posts manage and analyze increasing amounts of information, commanders need an informal way to balance the demands of the system of systems through their own intuition and that of their subordinates.[30]

Ironically, the commander's intent and battle command tenets seem diametrically opposed to current concepts of information superiority. Intent exists to guide the subordinate commander in the absence of specific information from higher, or in the presence of specific information that the superior does not have that causes a change in the mission. True information dominance could negate the purpose of intent and provide the capability that critics of information technology most fear: the detailed control of all forces by a centralized commander.[31]

---

[28] Gary B. Griffin, *The Directed Telescope: A Traditional Element of Effective Command* (Fort Leavenworth, KS: Command and General Staff College, 1991), 8.

[29] Manuel De Landa, *War in the age of intelligent machines*, Swerve ed. (New York: Zone Books, 1991; Reprint Cambridge, Mass: MIT Press, 1994), 60.

[30] John H. Jr. Tilelli, "Putting JV 2010 into Practice," *Joint Force Quarterly*, no. 17 (1998): 80

[31] Robert R. Leonhard, *Fighting by minutes : Time and the Art of War* (Westport, Conn.: Praeger, 1994), 113.

Shimon Naveh's summary of operational to tactical interfaces recognizes that "since military systems are structured hierarchically and their operational logic is from the rear to the front, it is only natural that the principal location of the operational commander should be in the rear."[32] Naveh's analysis describes mutually supportive focal points along the lines of operation:

> The tactical pivot, focuses on immediate and local matters, competes under the pressure of combat with unpredictable challenges, while exercising direct command from the front . . .[and] the operational pivot, which centers on holistic and future matters, functions from the rear by means of staffs and procedures, while attempting to initiate the deliberate occurrence of future events.[33]

The distinction between pivots presented allows different echelons to have competing information requirements. This commander-centric focus for information superiority has been criticized because the "definition is narrowly focused on technology and the movement of information rather than the idea of gaining knowledge or the more basic concept of enabling commanders to apply professional judgment while exercising command and control in combat."[34] In *War in the age of Intelligent Machines,* Manuel De Landa argues for a more distributed command and control synergy, because in

> . . . tactical command networks, friction appears as 'noisy data.' Not only information circulates in the circuits of command networks, but also the uncertainty produced by the fog of war . . . viewing military communications during battle [as a dissipating structure of self-organization] allows one to picture the task of the commander as … [tracking] the points at which friction may be dispersed within tactical, command systems in order to preserve the efficiency and integrity of the war machine during battle.[35]

Realistically, the friction of war may negate the commander-centric method of command and control by overloading intermediate communications channels with irrelevant information.

Divergence of Lines of information

The story of information in the United States Army is in part the story of the technical branch that the Congress created in 1860 solely to serve information—the Signal Corps. The

---

[32] Naveh, 132.
[33] Ibid.
[34] F.G. Hoffman, "Joint Vision 2010: A Marine Perspective," *Joint Force Quarterly*, no. 17 (1998): 36
[35] De Landa, 61.

initial impact of technology and the Signal Corps' concept of the line of information described in 1915 recounted that:

> Half a century ago rapidity of transmission of information in campaigns was generally measured by the speed of the couriers; distant movements were left to take care of themselves or neglected, since, if discovered, they could only be reported after the event; immediate operations were limited; the chessboard was small. . . . [now] the nerves extending from the controlling brain to the striking arm—that is, the lines of thought transmission—should be the most perfect, the most rapid, and the most certain that science can give.[36]

Lines of information, like lines of communication, connect bases of operations with other bases or with forces in motion and provide for the effective communications links to pass information for military purposes. Different levels of technology may transform the path and capacity of the lines of information, but they fundamentally connect the same elements. Physical transfer of information by courier must conform to the geography of the line of communication. Electrical and visual connectivity diverge from the line of communication in various degrees; telegraph and telephone wire were typically found along lines of communication, but signal flags and short range radios provide examples where a series of high points within visual range (or line-of-sight) of the line of communication were required as pivot points for effective information transfer. Satellite communications provide lines of information of enormous range with no relation to the traditional lines of communication.

Similarly, bases of information provide an area, system, or network from which a military force supports its offensive operations, to which it reaches back to for information, and in which tactical operations centers exist to process information. Army doctrine defines an "information environment" that surrounds the force and includes the presence of home stations in each unit's battle-space (or a strategic base of information).[37] The tactical operations center with associated communications nodes typically serves as the pivot point for the base of information. The computer increased the information storage and processing capability of the base of information at the same time as high capacity, long-range communications provided virtual lines of

---

[36] Scriven, 14.
[37] Headquarters Department of the Army, 5-9.

information via the troposphere or a satellite relay. Finally, the computer network provided the capability for countless virtual lines of information, computer to computer, from any base of information to any other.

The principles of command and control—responsiveness, mobility, survivability, and sustainability—provide some insight when compared to the concept of the line of information. Naveh derived three principles – indirect control from rear positions; maintaining situational awareness by passing orders forward and details back; and having an overall purpose based on the operational aim.[38]

Responsiveness consists of reliability, redundancy, and timeliness of information transmission. In his book *Command and Control for the Common Defense,* Kenneth Allard outlined the visual line-of-sight span of control of early commanders and their ability to tactically intervene in operations. The lack of timely, strategic communications by necessity required greater autonomy of forces operating at greater distances from the seat of government.[39] The current state of technology blurs the distinctions but must support both commander-centric and network-centric paradigms.

Mobility requires information systems to match the pace of the force in motion. Because lines of information can diverge from lines of communication, mobility can mean the ability to travel faster and farther than the operating force to establish data relays on high ground supporting the line of operations. Mobility could also be the ability of a satellite communications system to refocus a movable antenna on a particular line of operation for maximum effectiveness.

Survivability overcomes the possibility of a sudden, catastrophic loss of key information nodes and uses encryption to protect critical information from adversaries. One lost or misunderstood message can have exponential impact.[40] Old concepts of information war have

---

[38] Naveh, 132.

[39] Allard, 42.

[40] Joe Halloran, "Command and Control Interoperability," *Military Review* 66, no. 10 (October 1986): 39. Halloran argues that the disastrous charge of the Light Brigade at Balaklava, 25 October 1854, was due to “a series of errors within the British command and Control System.”

been repackaged in the modern definition of "actions taken to achieve information superiority by affecting adversary information . . . [and] information systems, … while defending one's own."[41] Survivability directly counters threat efforts at waging information warfare on friendly nodes.

Sustainability requires the ability to maintain a level of information transfer for extended periods. The rapid operational movement of forces does not necessarily correlate with ease of relocation of communications systems. Key systems might be required at critical nodes longer to support a depth of operational maneuver. Michael Ignatieff, in *Virtual War: Kosovo and Beyond*, addressed the vulnerabilities of technology in contemporary operations:

> For the central claim of the new technological gospel was that computers, battlefield sensors and spy satellites could dispel the 'fog' of war—the chaotic uncertainty in which battles unfold; and eliminate the 'friction'—adverse terrain, climate, equipment failure, troop morale and other incalculable factors—standing in the way of military victory. Generals like Norman Schwarzkopf were skeptical; they had bitter combat experience of both fog and friction in Vietnam.[42]

The pace of technological development might present the "risk of outstripping our ability to capture ideas, formulate operational concepts, and develop the capacity to assess results."[43]

Lines of Information and Transformation

Army transformation plans currently include the concept of an Interim Brigade Combat Team (IBCT), able to rapidly deploy and conduct limited decisive operations. The IBCT organizational concept relies heavily on robust information systems and the presence of an interim division for additional information support. Geographic separation beyond line-of-sight range of the support base precludes the use of terrestrial systems for interconnectivity. The organizational concept for the Army Forces (ARFOR) headquarters describes the importance of "reach-back" as "an electronic tether and enables the ARFOR to leverage organic and non-organic resources from outside the [area of operations] . . . reduces the ARFOR footprint . . .

---

[41] Headquarters Department of the Army, *Information Operations*., Field Manual 100-6. (Washington, DC: U.S. Government Printing Office, 1996), 2-2.

[42] Michael Ignatieff, *Virtual war : Kosovo and beyond* (New York: Henry Holt, 2000), 173.

[43] Joint Chiefs of Staff, *Joint Vision 2010*, 8.

without compromising its ability to accomplish it assigned missions . . . [and] enhances operational agility and further reduces force protection requirements."[44]

Implications for the transformation force include competition between forward deployed headquarters for limited "reach-back" capabilities and reliance on the higher headquarters to transfer the excess communications burden onto theater systems. The accelerated deployment timeline for the IBCT of ninety-six hours, with the potential for immediate employment in decisive operations, will further challenge the ability of organizations to establish and maintain the robust lines of information needed to support decisive operations. [45]

[44] Headquarters Combined Arms Center, *ARFOR Organization and Operational Concept (Draft)* [Online] (Headquarters, Combined Arms Center, 2000, accessed 2 February 2000); available from FTP://160.149.109.31/TF ARFOR/.

[45] Kenneth E. Viall, "Medium Brigade 2003: Can Space-based Communications Ensure Information Dominance?" (Thesis, Ft. Leavenworth, KS: U.S. Army Command and General Staff College, 2000), 95.

Chapter Three

Taming the Spark

Beyond the Natural Means

From ancient times, natural constraints have limited the transfer of information to the physical, visual, or acoustic methods. Available physical means offered the greatest range through runners, mounted couriers, pigeons, and even manned balloons. Van Creveld points to the use of messengers by Napoleon as a field army commander to control his subordinate corps during the 1806 battle of Jena-Aurstadt.[46] Acoustic means included the human voice pitched to a certain note, or the prearranged signals of a trumpet or cannon. Visual methods involved signal fires and various semaphores including the Chappe Telegraph system of relays adopted by the French before the Napoleonic wars.[47]

The science of electricity tamed the spark for speed-of-light transmission over wire and electro-magnetic wave. The telegraph, field telephone, and rudimentary spark-gap radio transmitters provided increasing benefits for lines of information. Strategic lines of information allowed the highest commanders, responsible for the overall strategy of a conflict, to coordinate the actions of large, dispersed forces over significantly extended distances. At the operational and tactical levels, as forces moved from established bases of information, how well were the fundamentals of courier, telegraphy, and radio integrated to support operational maneuver?

Morse's Telegraph and Myer's Signal Flags

Morse patented the telegraph system in the United States in 1837. After some development, Congress allocated funds for the construction of a telegraph line between Washington and Baltimore in 1843, beginning the expansion of telegraph links alongside

[46] Van Creveld, 86.
[47] William R. Plum, *The Military Telegraph During the Civil War of the United States* (Chicago: Jansen, McLurg & Company, 1882; Reprint Lacrosse, WI: Northern Micrographics, Inc., 1998), 11-23. Plum's analysis of ancient communications means introduces his own history of the military telegraph in the Civil War.

railroads throughout the country.[48] Early telegraph lines typically followed the tracks of the railroad, and the combination of fast and usually reliable information with the ability to move troops and supplies over long distances heralded sweeping changes in the overall strategy of war.[49] The Crimean War of 1854 provided an early example of an undersea military telegraph line between the base at Varna (Turkish empire) and the base at Balaclava on the Crimean peninsula.[50] Extending the speed of the telegraphic line of information beyond the end of the telegraph wire became the challenge for military commanders as they sought to integrate their traditional means of command and control with the new technologies.

Information Reach in the Civil War 1861

Doctor Albert Myer developed a hand signal system based on the Morse code alphabet for use by the deaf. He later adapted his system into a military signal flag system, which he patented in 1856.[51] Myer tested his signal flags during the 1860 Navajo Expedition to New Mexico and was designated the Chief Signal Officer of the Army at the start of the Civil War.[52]

The system of flag signaling developed by Myer provided the "first permanent line of communication" between Fort Monroe and Newport News and demonstrated an initial tactical responsiveness to information needs before installation of permanent telegraph lines.[53] The Civil War provided a testing ground for the new and experimental means of communications that significantly increased the effectiveness of the transmission of military intelligence. Union Army signal elements trained not only to establish stations of communication to relay messages, but

---

[48] Alfred Price, *The History of U.S. Electronic Warfare* (Westford, MA: The Association of Old Crows, 1984), 1.

[49] Larry H. Addington, *The patterns of war since the eighteenth century*, 2nd ed. (Bloomington: Indiana University Press, 1994), 48.

[50] Tony Devereux, *Messenger Gods of Battle: Radio, Radar, Sonar, the Story of Electronics in War* (New York: Brassey's (UK), 1991), 8.

[51] Joseph Willard Brown, *The Signal Corps, U.S.A. in the War of the Rebellion* (Boston,: U. S. Veteran Signal Corps Association, 1896), 20.

[52] Kathy R. Coker and Carol E. Rios, *A Concise History of the Signal Corps* (Fort Gordon, GA: United States Army Signal Center and Fort Gordon, 1988), 8.

[53] Brown, 42. Myer had apprenticed with a telegraph company before becoming a surgeon.

also stations of observation to observe and report on enemy and terrain features within view—a rudimentary sensor network.[54]

Confederate forces gained the services of Lieutenant E.P. Alexander at the battle of Bull Run in July 1861.[55] Alexander, who had helped Myer test the signal flag system, established a Confederate signal element for the battle, and while observing one of his signal stations at the Stone Bridge through a telescope, observed a glint of sunlight at a distance and "discovered McDowell's column . . . north of Sudley Ford crossing Bull Run and turning our left flank, fully eight miles away. . ."[56] Recognizing the danger to Colonel Nathan Evans' small force, in the path of the Union's main attack, Alexander wrote that he

> . . . signaled Evans quickly, 'Look out for your left; you are turned.' Evans afterwards told me that a picket, which he had had at Sudley, being driven in by the enemy's advance guard, had sent a courier, and the two couriers, one with my signal message and one with the report of the picket, reached him together. The simultaneous reports from different sources impressed him, and he acted at once with sound judgment.[57]

If signal flags provided the tactical information advantage for the Confederates at Bull Run, telegraph lines and interior rail lines provided the strategic advantage. Seeking reinforcements, General B.G Beauregard wired Jefferson Davis and Davis telegraphed General Joseph Johnston to move from Harper's Ferry to reinforce at Bull Run.[58] Despite the tactical advantage provided by Alexander's signal corps allowing the delay of attacking Union forces, the arrival of Johnston's forces provided the decisive force required to win the first battle of the war for the Confederates.

In contrast to the Confederate ability to use information at Bull Run, Union forces did not extend the telegraph beyond Harper's Ferry to Robert Patterson's force opposing Johnston.[59]

---

[54] Ibid., 125.

[55] Rebecca Robbins Raines, *Getting the message through : a branch history of the U.S. Army Signal Corps*, Army historical series (Washington, D.C.: Center of Military History U.S. Army, 1996), 23.

[56] Brown, 44 .

[57] E.P. Alexander, *Military Memoirs of a Confederate* (New York: Charles Scribner's Sons, 1912), 30.

[58] W. Glenn Roberston, "First Bull Run, 19 July 1861," in *America's First Battles, 1776-1965*, ed. Charles E. Heller and William A. Stoft. (Lawrence, KS: University Press of Kansas, 1986), 95.

[59] L.H. Korty, "The Telegraph in the Civil War," in *Civil War Sketches and Incidents* (Nebraska: Commandery of the State of Nebraska, 1902), 205.

Patterson had actually withdrawn out of contact with Johnston and telegraphed the war department first that Johnston had been reinforced, then that Johnston had left with a significant portion of his force. Myer had envisioned the need for a field telegraph system but could not convince the War Department.[60] Myer personally arrived too late to the battlefield to provide any tactical information support. As a result, Brigadier General Irvin McDowell had to organize a line of couriers over the ten-mile distance from Bull Run to the closest telegraph station at Fairfax Court House.[61] One military telegraph operator, David Bates, recounted the tale of the War Department directly contacting a telegraph operator in Springfield, Virginia, charging him to keep his office open until released by the War Department to report on the withdrawal of Union forces.[62]

After Bull Run, Myer trained and organized signal teams of soldiers detached from regular units with the expectation of providing mobile, responsive communications organic to each Army regiment. Signal teams accompanied the naval expedition to Port Royal in November 1861, and supported inter-ship and ship-to-shore communications and extended the line of information twelve miles inland from the landing area.[63]

By 1862, Myer had developed a system of telegraph wagon trains, each carrying seven miles of wire, that installed a tactical wire during the battle of Fredericksburg in December that year.[64] In 1863, the information requirements between Union General Hooker and his chief of staff ten miles away overloaded the capabilities of the visual and field telegraphic lines of information, and the "inadequacy of the Union's field communications contributed to the failure of the Chancellorsville Campaign."[65]

---

[60] Brown, 172. See also Raines.

[61] Plum, 76.

[62] David Homer Bates, *Lincoln in the Telegraph Office: Recollections of the United States Military Telegraph Corps During the Civil War* (New York: The Century Co., 1907), 93.

[63] W.G. Fuller, "Reminiscences of the Signal Service in the Civil War," in *Personal Narratives of Events in the War of the Rebellion* (Providence, RI: Rhode Island Soldiers and Sailors Society, 1899), 446.

[64] Brown, 174.

[65] Raines, 20.

The Military Telegraph Corps, a separate division of the War Department, took control of all military telegraphy and standardized the telegraphic field trains traveling with Union forces.

> Reels, carrying a mile of fine insulated wire each, were fitted to pack saddles borne by mules. Portable batteries were placed in the pack saddles. Small telegraph instruments capable of being placed in the vest pocket were supplied to operators in the field. Whenever a marching army took up a position, or halted for the night, the much-abused mule was trotted off with his load, the wire unreeled and attached to the batteries . . . thus in a short space of time the telegraph was ready to transmit orders, exchange advices and exercise a vigilance and protection over the surrounding camps.[66]

Recognizing the telegraph's vulnerability, the Confederate Army attached signal teams to their cavalry raiding parties to disrupt communications or tap lines to intercept traffic. Interior lines aided in the maintenance of communications. Armies traveling into hostile areas soon found that their telegraph lines became easy targets for guerilla forces and local citizens. Commanders soon took personal interest in their telegraph lines, and "so important did Hooker regard it in his Chancellorsville fight, that he detailed two regiments to guard the wires."[67]

For security, Myer prescribed a system of cipher disks to protect flag communications throughout the war.[68] The Confederate Signal Corps developed their own Court Cipher system that the Union decoded, allowing an information advantage to the Union intelligence effort. The Military Telegraph department also carefully constructed ciphers to protect transmissions.

Commonality of signal methods between Union and Confederate forces allowed the signal elements of both armies to intercept any visual signaling of the opposition. Civil War signalman Willard Brown describes an example where Lieutenant General Jubal Early during the Valley Campaign sent a false message to himself (ostensibly from James Longstreet) that they would attack Union General Philip Sheridan together. Sheridan's signal officer also viewed the message and relayed it to General Ulysses Grant.[69] The new communications methods had

---

[66] Korty, 206.

[67] W.G. Fuller, "The Corps of Telegraphers under General Anson Stager During the War of Rebellion," in *Sketches of War History 1861-1865*, Papers read before the Ohio Commandery of the Military Order of the Loyal Legion of the United States (Cincinnati: Robert Clarke & Co., 1888), 400. See Also Fuller, 401, and Plum, 166.

[68] Brown, 99. Myer recognized the requirement that Signal Officers be "practiced in the duties of reconnaissance, . . . skilled also in the arts of cryptography and telegraphy, and familiar with ciphers."

[69] Ibid., 212-213.

provided an economy of force to deception operations that had previously relied on more elaborate means.

At Vicksburg, "Grant was enabled to watch Pemberton's every move and to communicate constantly with Sherman . . . ."[70] When General Grant assumed the role of top military advisor, and became theater commander around 1864, he relied on the telegraph system to relay his strategy to units scattered across the country. Later, nine telegraph operators and numerous signal sections accompanied Sherman in his march to Savannah, tapping Confederate lines for intelligence, but remaining strategically out of touch with Grant until reaching the sea.[71]

Spanish American War and the Birth of Reach-back

After the Civil War, the commercial application of technology continued. The telegraph system expanded with the railroad construction in the west. By 1881, five thousand miles of telegraph line existed. The drive to develop communications continued in the formation of telephone links in Washington, D.C., in 1878. Most army establishments would soon have telephone links.[72] Despite shortfalls uncovered during the Civil War, innovations in tactical communications did not meet with universal acceptance due to "the tenacity and extreme conservatism of the ranking officers of the army in opposing any new methods of service—the cavalry experts, for instance, discredited any way of conveying military information save by mounted messenger."[73]

The Spanish-American War added impetus to continue the rapid development of military communications. President McKinley charged Major General Adolphus Greely, chief signal officer in 1898, with preparation for the impending conflict with Spain. Greeley was empowered to control civilian telegraph lines linking overseas locations with New York City, Tampa, and

[70] Korty, 207.

[71] Ibid., 208.

[72] Dulany Terrett, *The Signal Corps: the emergency (to December 1941)* (Washington,: Office of the Chief of Military History Dept. of the Army, 1956).

[73] A. W. Greely, *Reminiscences of adventure and service; a record of sixty-five years* (New York: Charles Scribner's Sons, 1927), 152.

Key West, Florida, and to censor messages for operational security.[74] Greely formed a voluntary Signal Corps by act of Congress to overcome deep cuts in force structure after the Civil War. His efforts paid dividends when a signal officer found telegraphic intelligence revealing the presence of the Spanish Fleet in Santiago, Cuba, contrary to the Navy's expectations. Despite the warning, the Navy took nine days and a succession of orders to route their fleet to blockade the port.[75]

General William Shafter and the V Army Corps deployed to Cuba to destroy the Spanish Fleet in Santiago port. At the time, few army corps commanders recognized a need for signal capabilities. Reflecting this feeling, Shafter had rejected the signal corps offer of a telegraphic train to accompany his Corps.

> The details of Shafter's refusal disclose the attitude of this general leading an army into the field. Learning by letter that our field telegraph train was not being loaded on transports, I telegraphed in code to Colonel Green, Shafter's Signal Officer: "Impress on Shafter the importance of an Army carrying its own means of communications into an enemy's country. Inform him that the best telegraph train in the world is under you at Tampa.' In a few hours Green replied in code: 'Shafter says he only wants a man with a gun on his shoulder.' So the army sailed without telegraph, telephone, or even a call bell.[76]

Despite such opposition, Greely believed the "absence of speedy communications might spell disaster."[77] He initiated a plan to provide both strategic and operational information support to deploying forces. Greely's plan had two objectives:

> First, to submarine cable work, involving the destruction of the enemy's system, the repair of friendly lines, and the laying of war cable for our own army, so as to bring it into speedy communication with the President and War Department; second, to cover the entire front of Fifth Army Corps, in its advance, with a network of telephone lines, so that its movements in action could be under one controlling mind.[78]

Greely secretly acquired the assistance of the Western Union telegraph company to charter the cable-laying ship *Adria*, acquire submarine cable, and coordinate for telephones and other materials needed for the war. Colonel James Allen sailed with the *Adria* in June 1898 to Santiago to find and sever Cuban telegraph cables outside the port, cutting two of three lines

[74] Ibid., 179.
[75] Raines, 88.
[76] Greely, 185.
[77] Ibid., 186.
[78] Ibid.

before Spanish guns made the effort untenable. Allen then repaired the French cable to Haiti and "on the night of June 20 he opened station on [the *Adria*] and telegraphed . . . that the Fifth Army Corps had arrived off Santiago."[79] Although Shafter did not disembark his troops for two more days, the Signal Corps had already established a telegraphic link to the President that today might be called "reach-back." Subsequent operations ashore proved the efficacy of Greely's signal support plan and contributed to V Corps operations. For the first time, telegraph switches allowed messages to be routed directly from Washington to the foxholes in a foreign land.[80]

Maxwell's Theory and Marconi's Radio

While the telegraph harnessed the spark, in 1865 James Maxwell attempted to understand the spark and the relationship between electricity and magnetism.[81] Maxwell's theory predicted that electromagnetic effects rippled like waves and could "travel great distances."[82] Demonstrated by Heinrich Hertz in 1888, the newly found electromagnetic waves led to experiments involving the rapid transmission of messages over the air. Maxwell's theory had unlocked the door to the electromagnetic frequency spectrum. By the 1890's, Italian inventor Guglielmo Marconi developed a short distance spark-gap wireless telegraph system with a range of two miles. The obvious military interest in the new technology provided the impetus for extending the range of the radios. By 1897, Marconi had developed a radio set which linked the Italian armored Cruiser San Martino with the shore 11 miles away.[83]

The United States Signal Corps began the implementation of these spark-gap transmitters capable of sending Morse code signals. By 1908, major military bases and ships employed the transmitters, and a portable set had been developed for wagon or pack mule.[84] With the

[79] Ibid., 190.
[80] Coker and Rios, 13.
[81] Frederick J. Beuche, *Introduction to Physics for Scientists and Engineers*, Third ed. (New York: McGraw Hill, 1980).
[82] Devereux, 12.
[83] Price, 2.
[84] Coker and Rios, 16-17.

development of radio, lines of information entered a new dimension beyond the physical line of communication.

Into the Spectrum, World War I 1914-1918

In 1905, German war planner Alfred Graf Schlieffen presented a plan for rapid national mobilization and deployment to quickly envelop the French army by maneuvering through Belgium and then swinging south around Paris to flank the French army.[85] Germany organized its first signal company in 1888 and by 1905 established a strategic line of information via courier and telegraph, linking the monarch to his field commanders. The Germans also had tactical telegraph systems that could move with corps headquarters.[86] Though telegraphic messages could travel for hundreds of miles through relays, the tactical voice telephones available suffered from a range limitation of twenty-five miles. Germany organized radio telegraph units under each telegraph battalion starting in 1905 to overcome the limitations on the speed of installation that tactical telegraph lines imposed on a moving army. By 1910 the field wire telegraphs were "virtually discarded by the German army as obsolete."[87]

At the outbreak of World War I in 1914, German Commander General Helmuth von Moltke and his headquarters settled "150 miles from his decisive right wing, [where] he tried to direct operations."[88] Moltke, worried about centrally managing simultaneous operations against France in the west and Russia in the east, failed to properly control his three western field armies by delegating control to one unified western commander.[89] At Moltke's headquarters in Coblenz,

> Already they found their telecommunications net inadequate and old fashioned; the field armies were receding into a fog of scanty, garbled, and hopelessly delayed messages . . . The problem of long distance control was sharply posed by Prittwitz's decision, endorsed by Moltke, to abandon East Prussia . . . [Moltke's staff] set out to reverse it by telephoning the staff of each of Prittwitz's corps to see if things were as bad as he made out. From Coblenz to East Prussia lay more than nine hundred kilometers of telephone

---

[85] Correlli Barnett, *The Swordbearers; Studies in Supreme Command in the First World War* (London: Eyre & Spottiswoode, 1963; Reprint Indiana: Indiana University Press, 1975), 16.

[86] Arden Bucholz, *Moltke, Schlieffen, and Prussian War Planning* (Providence, RI: Berg Publishers, 1991; Reprint Paperback, 1993), 184.

[87] Ibid., 240.

[88] Van Creveld, 154.

[89] Barnett, 44.

> wire without amplifiers. It took long hours of struggle, frustration, and shouting into mouthpieces before the operations staff could assemble notes on each corps' situation.[90]

The staff convinced Moltke to countermand the retreat in the east. Moltke similarly attempted to modify the Schlieffen plan and ordered the extreme right flank to orient from the north of Paris to the Marne, but his message "took twelve hours to reach [his commanders]; German communications were now sliding from inadequacy to collapse."[91]

The limited range of the wireless radio traveling with First Army required a series of radio relays to transmit messages, further degrading efficiency and responsiveness. German doctrine of lower echelons maintaining communications with higher headquarters was flawed during rapid movements, since the "responsibility for establishing communications always lay with subordinate units placed under the command of tactical officers whose primary goal was march discipline, not communications."[92] Martin Van Creveld's analysis maintains that this concept was impossible with wire systems, and although the radio worked well it had insufficient range and message capacity.[93] The German army had reached a point of information culmination on an over-extended line of information. Conversely, the French concentration around Paris leveraged interior lines of information present in their communications infrastructure. German doctrine later sought to overcome the information culmination previously encountered by decentralizing control to lower levels during the March 1918 German offensive.[94]

The ensuing stalemate and period of trench warfare would provide enough close range interference between radios to allow wire communications to be favored over wireless.[95] During the July 1916 Somme Offensive, preparations for the offense, including the extension of telephone and telegraph lines buried up to six feet deep at the front lines (to prevent disruption by enemy artillery), "had one disabling shortcoming: it stopped at the edge of no-man's-land. Once the troops left their trenches…they passed beyond the carry of their signals system into the

[90] Ibid., 50.
[91] Ibid., 64.
[92] Bucholz, 281.
[93] Van Creveld, 254.
[94] Ibid., 182.
[95] Allard, 83.

unknown."[96] Attacking forces were provided expedients, such as "Morse shutters, semaphore flags, and carrier pigeons; but none were to prove of real use."[97] The example shows the relevance of the courier still, because "as soon as the waves of cannon fodder disappeared into the smoke, only the thinnest lines of communication remained open: soldiers running back and forth from one side to the other of no-man's land"[98]

General John J. Pershing's American Expeditionary Force in 1917 sought to overcome communications limitations by "elaborate planning and prescribed schemes of maneuver."[99] Army signal planners revised estimated requirements for wire from a thousand miles to sixty-eight thousand miles per month, straining United States industrial capabilities.[100] On October 6, 1918, Major Lyman Frasier, serving with the 1st Division, wrote that during the Meuse-Argonne offensive the division established procedures to ensure communications. Battalion commanders were told "their chief duty was to advance but that next to this their most important function would be to keep in touch with regimental headquarters . . . ."[101] Other measures taken included guarding every 500-yard section of wire, establishing effective courier service, and providing redundant couriers when passing critical messages.

Across the Spectrum, World War II

World War I provided the catalyst to advance radio technology. Spark-gap transmitters operated inefficiently, using excessive bandwidth by modern standards. Inventors sought ways to tune radios to narrower frequency bands.[102] By World War II, maturing radio systems allowed

---

[96] John Keegan, *The Face of Battle* (The Viking Press, 1976; Reprint New York: Penguin Books, 1978), 264.
[97] Ibid., 265.
[98] De Landa, 73.
[99] Allan R. Millett, "Cantigny, 28-31 May 1918," in *America's First Battles, 1776-1965*, ed. Charles E. Heller and William A. Stoft. (Lawrence, KS: University Press of Kansas, 1986), 161.
[100] Benedict Crowell, *America's Munitions 1917-1918* (Washington, DC: Government Printing Office, 1919), 568.
[101] Infantry Journal, *Infantry in Battle*, Second ed. (Washington DC: The Infantry Journal, Incorporated, 1939; Reprint U.S. Army Center for Military History, 1997), 192.
[102] Army War College (U.S.), *The Signal Corps and Air Service. A study of their expansion in the United States, 1917-1918*, Monograph no. 16 (Washington, DC: Govt. Print. Off., 1922), 22.

commanders personal flexibility on the battlefield. New portions of the frequency spectrum provided flexibility in range, clarity, and mobility of systems.

Allied Expeditionary Forces landed in Africa in November 1943 to conduct Operation Torch. During the amphibious landing, British communications ships overcame an ineffective United States communications support plan, since the majority of American radio trucks had remained stowed away in transports. Conflicting codes and ciphers presented interoperability challenges for allied forces. United States forces used new radio relay equipment with extended range to provide multiple circuits, relatively low-probability of intercept, ship-to-shore communications, and jungle penetration capability.[103]

The 57th Signal Battalion supported VI Corps, and its additional three divisions, on the beach at Anzio, Italy. Starting on May 23, 1944, VI Corps conducted a nineteen-day operation to link up with Fifth Army.

> The breakout from Anzio presented extremely severe requirements for all signal elements because of the large number of major units controlled by VI Corps, the complex tactical movements required during the breakout, and the following rapid pursuit to Rome and north. This called for the utmost endeavor . . . to furnish the necessary communication for the Corps. . . . The rapidity of the advance led to extreme distances between division command posts and Corps. The Advance Corps Command post moved five times during this period.[104]

On June 6, 1944, Joint Assault Signal Companies landed on the beaches at Normandy and, although unable to run wires to ships as planned, provided radio links as an interim capability.[105] The First Army created command vans with installed communications devices to support rapid moves. Amplitude modulation (AM) hand radios in infantry squads could not talk with new frequency modulation (FM) radios in artillery and armor units. However, General George Patton's newly formed Third Army did not have adequate equipment. Patton reformed

[103] Raines, 276-292.

[104] William B. Harley and Hale Mason, eds. *History of the 57th Signal Battalion Word War II: February 10, 1941 to September 29, 1945* (New York: 1984), 19.

[105] George Raynor Thompson and Dixie R. Harris, *The Signal Corps: the outcome (mid-1943 through 1945)* (Washington,: Office of the Chief of Military History U.S. Army; [for sale by the Superintendent of Documents U.S. Govt. Print. Off.], 1966), 231.

the 6th Cavalry Group into the nucleus of the Third Army Information Service.[106] Liaison officer patrols began to "visit command and observation posts of units in contact with the enemy, as well as exchange information with subordinates. . . ."[107]

After landing in France, the 57th Signal Battalion again kept pace with VI corps, where the Corps command post, often fifty miles from it's subordinate divisions, moved daily. Captured vehicles provided additional mobility that organic structure could not. Maximum use of existing French wire counteracted the poor topography that limited line-of-sight radio transmissions. [108] Years of experience had integrated existing technology and organizations to adapt to maintain lines of information for forces in motion.

The War in the Pacific provided similar examples of an adaptation of information to support maneuver. Amphibious operations used the fleet as a base of information until a beachhead could be established. E.B. Sledge, in *With the Old Breed*, recounts difficulties during the amphibious assault on Pelelieu and the lack of communications.

> That our battalion executive officer had been killed a few moments after hitting the beach and that the amtrac carrying most of our battalion's field telephone equipment and operators had been destroyed on the reef made control difficult. The companies of 3/5 [battalion] lost contact with each other and with 3/7 on our flank.[109]

Upon establishment of secure beach heads, operations inland followed the same techniques demonstrated in the European Theater. Later in the war, General Douglas MacArthur's Chief Signal Officer, Spencer B. Akin, recalled that "Sixth Army Troops—including their commander, Lt. Gen. Walter Kreuger—complained that mobile communications clogged Highway 3 with a long column of heavy Signal Corps' vehicles, during the recapture of Manila in the Philippines near the end of the war."[110]

---

[106] Dean A. Nowowiejski, "Concepts of Information Warfare in Practice: General George S. Patton and the Third Army Information Service August-December, 1944" (Monograph, School of Advanced Military Studies, 1995).

[107] Griffin, 27.

[108] Harley and Mason, eds.,, 28.

[109] E. B. Sledge, *With the old breed, at Peleliu and Okinawa* (New York: Oxford University Press, 1990), 65.

[110] Carol E. Stokes-Rios, "MacArthur Relied on the Signal Corps," *Army Communicator* 13, no. 4 (Fall 1988): 17.

Spreading the Spectrum, Korea 1950

In 1950, Eighth Army established its headquarters in Taegu, Korea, a robust communications hub. The army, absent its two corps-level signal battalions, provided direct support to divisions despite poor roads, mountainous terrain, and extreme weather. The ebb and flow of forces south of Seoul, back north again via the landing at Inchon, then up toward Pyong-yang and the waiting Chinese, placed a significant burden on the 7th Signal Company supporting X Corps to maintain communications.[111] In the initial withdrawal south of Eighth army, civilian infrastructure of use to the enemy including the "signal service was destroyed as completely as were the transportation facilities."[112]

Wire communications in Korea was limited to twenty-five miles between stations. Very high frequency (VHF) radio systems overcame wire limitations but required the use of strategic high ground to acquire line-of-sight connectivity. Communicators struggled to haul VHF equipment weighing over two tons to remote hilltops. Radio teams found ways to "bend" signals along riverbanks and around large mountain masses to exceed the twenty-five mile nominal range of the radio. In one example, the ninety-mile distance between Seoul and Taegu was bridged by a 140-mile, two-link VHF radio relay.[113] VHF systems provided initial connectivity mobile enough to keep pace with operational movement, and became the backup links once wire communications were established.[114] However, frequency interference with Chinese operators and night-time atmospheric conditions hampered radio effectiveness.[115]

During the October 1950 United Nations offensive into North Korea, the Fourth Signal Battalion "radio and radio relay teams . . . had been trucked and airlifted almost like postage

[111] Raines, 322.

[112] Roy Edgar Appleman, *Disaster in Korea: The Chinese Confront MacArthur* (College Station, TX: Texas A&M University Press, 1989), 321.

[113] John Glendower Westover, *Combat support in Korea* (Washington,: Combat Forces Press, 1955), 89.

[114] Ibid., 97.

[115] Philip Warner, *The Vital Link: The Story of Royal Signals 1945-1985* (London: Leo Cooper Ltd., 1989), 124. The Ionosphere is a variable layer of the earth's atmosphere that reflects high frequency radio waves back to earth over long distances.

parcels to support the Corps' northward advance."[116] When Chinese forces attacked a radio relay team supporting the corps command post, signal soldiers were forced to defend their position while retrieving radio and power generation equipment to withdraw to an adjacent hill occupied by a Marine company. Upon assuming command of Eighth Army, General Matthew Ridgeway stressed the importance of units maintaining communications by any means, including runner, despite signal equipment destroyed by the Chinese.[117]

Lessons of the Spark

Through the 19th Century to the Korean War, the innovations in methods of communication, along with advanced weapons and tactics, signaled a new challenge to military leaders. Lines of information increased in speed due to the advances in electrical telegraphy. Lines of information jumped tentatively across the electromagnetic spectrum, then spread to different frequency bands and increased capacity and range. As forces moved from established bases of information, the line of information devolved to the rudimentary basics. Wire systems could not adequately keep pace with extended maneuver. Radio provided increased mobility but also imposed both range and capacity limitations. An improved VHF system provided an increased capacity for transmission of multiple lines of information over one radio.

Time to establish systems, coupled with the security of interior lines, supported an information advantage. During operational pauses, the luxury of time also allowed for the installation of wire and radio systems at new bases of information. Leveraging an information advantage during operational maneuver required careful planning based on the limits inherent in

---

[116] Kenneth E. Shiflet, "Communications Hill in Korea," in *The story of the U.S. Army Signal Corps*, ed. Max L. Marshall (New York,: F. Watts, 1965), 189.

[117] Eliot A. Cohen and John Gooch, *Military misfortunes : the anatomy of failure in war* (New York: Free Press, 1990), 189.

each new technology. As lines of information devolved to the most rudimentary means available at greater distances from the base of information, the overall operational aim of the force guided subordinate echelons to act independently based on better relative local information.

Chapter Four

Nexus of Space and Silicon

Vacuum Tubes to Transistors

Before 1950, the vacuum tube served as the heart of amplifiers and early computers, driving the size of electronic equipment. In 1951, William Shockley invented the first transistor—a device that could efficiently replace the vacuum tube.[118] Transistors allowed tremendous reduction in size, weight, and power requirements for electronic equipment used during the Vietnam War.[119] The integrated circuit condensed the equivalent of a larger number of transistors into one silicon chip, allowing even greater reliability and miniaturization. Continued development led to advanced satellites and the first microcomputers. Gordon Moore, cofounder of Intel Corporation, noted that the processing power in each generation of computer chip doubled every eighteen months while the cost remained constant.[120]

Radio engineers constructed tropo-scatter systems to reflect high-energy radio beams off moisture in the troposphere (a layer of the atmosphere) to provide connectrivity up to 400 miles. Communications satellites tested between 1958 and 1960 provided the next generation in communications by actively receiving and retransmitting signals over entire sections of the globe. Commercial industry launched the first permanent communications satellite in 1962, increasing capacity with each new launch incorporating the latest electronics.[121] From the Korean War to the mid-eighties, military organizations continued to refine the methods of passing information by integrating the technological advances in radios, satellites, and computers. Did innovations in

---

[118] Albert P. Malvino, *Electronic Principles*, Third ed. (New York: McGraw Hill, 1984), 113. *The Science of the Transistor* [Online] (2000, accessed 27 November 2000); available from http://www.pbs.org/ /transistor science.

[119] Van Creveld, 238.

[120] Larry Downes and Chunka Mui, *Unleashing the killer app: digital strategies for market dominance* (Boston, Mass.: Harvard Business School Press, 1998), 22.

[121] John D. Bergen, *Military Communications: A Test for Technology*, United States Army in Vietnam (Washington, DC: Center of Military History, United States Army, 1986), 31.

satellite communications and enhanced processing of the early data systems meet the demands of command and control systems during operational maneuver?

Small Wars and Satellites

Taking the High Ground, Vietnam 1963-71

At the onset of US involvement in Vietnam, the military line of information to the region consisted of a single undersea cable that linked Pacific Command in Hawaii with the Philippines, then extended over high-frequency radio to Vietnam.[122] The first military satellite link to Hawaii provided one telephone and one tele-type circuit. Capacity expanded to sixteen circuits by October 1964, and peaked at twenty-two military channels. To meet increasing requirements, the military leased an additional ten commercial circuits.[123] The strategic line of information eventually included the installation of military undersea cable to the Philippines and between ports along the coast of Vietnam.

The United States Military Advisory Command, Vietnam (MACV), activated in 1962, required an improved base of information to prepare for future operations. Tropo-scatter radio provided a backbone communication system between locations more than 200 miles apart to "pass over the vast distances of under-populated, enemy-infested terrain to connect the major operations and population centers in the Republic of Vietnam north of Saigon."[124] Abnormal atmospheric effects in January 1965 caused the loss of the troposcatter links and required a Defense Communications Agency team to deploy to determine the cause.[125]

Initial military advisory support in Vietnam quickly revealed the impact of terrain, weather, and enemy forces. With the threat to couriers due to the insurgency, emphasis shifted to the use of long-range radio communications.[126] To support the Government of South Vietnam

[122] Raines, 360.

[123] Thomas G. Rienzi, *Communications-Electronics, 1962-1970*, Vietnam Studies (Washington, DC: Department of the Army, 1972), 94.

[124] Ibid., 8. The large radio terminals were mounted on three large semi trailers, with mobile 30-foot antennas and 60-foot permanent antennas set in concrete.

[125] Bergen, 120.

[126] Ibid., 162.

counter-insurgency program "Strategic Hamlet," US signal elements installed high frequency "radio communication from more than two thousand villages and hamlets to district and provincial capitals by 1963."[127]

In November 1964, North Vietnamese patrol boats attacked United States naval forces in the Tonkin Gulf. Four Americans were also killed in a mortar attack on an airfield the same month. Political reaction led to the deployment of additional combat forces to the region starting in May 1965 with the 173rd Airborne Brigade and the new air-mobile 1st Cavalry Division.[128] General William Westmoreland, MACV Commander, directed each major subordinate command be connected to the operations center at MACV headquarters in Saigon via mobile radio-teletype.[129]

Signal support doctrine based on the conduct of conventional military operations dictated establishment of an theater area communications network into which tactical forces would connect their command posts. Area communications grids using line-of-sight radio meant less cable was required.[130] The geography and missions assigned to combat forces in Vietnam expanded the depth of a division sector from the doctrinal 200 to 300 square miles to up to 5,000 square miles.[131] Adapting doctrine to the situation, planners noted two considerations:

> First, the area communication paths either connected regional nodal centers or extended the tails to isolated elements that were not organically self sufficient. Second, the geographical distribution of base camps and other vital installation dictated a linear, rather than a rectangular, arrangement. The classic grid advantage was preserved, however, by the brigade's capacity to provide alternate routes between key points.[132]

Communications planners, lacking precise requirements, decided to "draw circles or 'goose eggs' around a population center or land area and then estimate the probable troop density within that area."[133] Based on density, planners could extrapolate switchboard, radio, and circuit

[127] Raines, 362.
[128] Andrew F. Krepinevich, *The Army and Vietnam* (Baltimore: Johns Hopkins University Press, 1986), 95.
[129] Raines, 366.
[130] Ibid., 367.
[131] Rienzi, 63.
[132] Ibid., 49.
[133] Bergen, 55.

requirements and then attempt to include enough inherent capability to support operations. The division signal planner was

> Forced to determine his own requirements, then present them to the commander [whose requirements] where generally unknown unless his dissatisfaction was expressed. This practice, then, contributed directly to uncontrolled inflation of communication requirements . . . [and] in turn to continual requests for resources to fill those requirements.[134]

The systems available could not support the inflated requirements, and by the summer of 1965 a thirty percent deficit existed, with up to 61 percent shortage on the Saigon to Nha Trang link.[135]

Although the long range of the backbone troposcatter radio systems negated the requirement for a large number of repeater stations, tactical command post placement often dictated the occupation of high ground by signal teams to ensure line-of-sight connectivity. First Infantry division established a permanent signal site on Nui Ba Den (Black Virgin Mountain) for VHF relay and FM retransmission. The mountain served as an information pivot point that connected the division command post with other echelons in Vietnam. Although the Viet Cong were initially permissive of the presence of signal relays, the protracted conflict saw a rise in the number of attacks on signal sites and a disruption of operations.[136] Major General Charles Myer, commander of the 69th Signal Battalion in Vietnam 1965, noted "since there were no battle lines, there were no secure areas outside base camp and fire base perimeters. Any high ground occupied as a communications site had to be totally secured, a necessity that drained combat resources sorely needed elsewhere."[137]

Selection of An Khe as the base for 1st Cavalry division was prompted by the existence of "twelve different locations within a ninety-mile radius of An Khe [that] were physically tested for multichannel and FM Radio coverage, and these sites governed subsequent command post displacements."[138] The division sent its Tactical Command post to Pleiku with signal support

[134] Ibid., 56.
[135] Rienzi, 35.
[136] Raines, 384.
[137] Charles R. Myer and United States. Dept. of the Army., *Division-level communications, 1962-1973* (Washington, D.C.: Government Printing Office, 1982), 25.
[138] Ibid., 28.

assets air lifted by helicopter. Radio relay was required to reach the brigade headquarters. Recognizing the weakness of the radio systems, the 13th Signal Battalion

> . . . mounted radios in fixed wing aircraft that circled at 10,000 feet and used them to retransmit voice messages between the widely dispersed combat units on the ground. This approach overcame the limitations of line-of-sight ground-based FM radio by increasing the range of PRC-25 [FM Radio] signals from five to sixty miles and by nullifying the effects of triple canopy jungle growth that absorbed electromagnetic transmissions.[139]

Units began equipping helicopters with onboard consoles that allowed battalion and brigade commanders to communicate with tactical ground forces and relay information. During the battle at Landing Zone X-ray, airborne retransmission would prove critical to Lieutenant Colonel Hal Moore's battalion for coordinating fires with supporting Air Force elements.[140]

Security of the lines of information came into question when MACV monitoring of tactical radio communications revealed that United States forces often did not follow signal-operating instructions (SOI) to use rotating call signs and ciphers to protect operational information.[141] Early portable encryption devices added too much weight to tactical radios to make automatic voice encryption feasible. Increased usage of radios by all parties to the conflict caused frequency conflicts as well. During operations, planners learned to postpone prescribed frequency changes mid-battle to avoid loss of contact. On one occasion when a friendly SOI was captured, the unit switched to a reserve edition, which Vietnamese forces also subsequently captured. Despite almost certain compromise, the unit continued to use the reserve SOI for the duration of the battle to maintain command and control.[142]

During the October 1967 Battle for Dak To, rugged terrain hindered the connection between the 4th Infantry Division tactical command post at Dak To and the main command post at Camp Enari 88 kilometers away. Both command posts had been located in depressions surrounded by mountains. The 124th Signal Battalion responded by engineering a multiple relay

---

139 Raines, 368.

140 Harold G. Moore and Joseph L. Galloway, *We were soldiers once -and Young: Ia Drang, the battle that changed the war in Vietnam*, 1st ed. (New York: Random House, 1992), 151.

141 Bergen, 399.

142 Ibid., 259.

radio link that exceeded the rated range of the communications systems. Prior testing and selection of precise antenna placement and operational frequencies had revealed unexpected capabilities.[143] With no intermediate radio relay site available, no coherent plan existed for convoy communications for forces moving between the bases and Dak To. Units also had no radio connection to the element assigned to provide route security, despite North Vietnamese fighting positions existing in range of convoy movement.[144] Lines of information were constrained by enemy presence.

Further innovations introduced a new form of information transfer in the first rudimentary data transmissions. Initially, data processing centers slowly and manually transferred data cards to interface the strategic and theater message systems. The newly created Automatic Digital Network (AUTODIN) increased message handling speed and "could process both message (teletypewriter) and data."[145] AUTODIN message switches operated like telephone switches as a central hub connected to other switches over circuits that used various transmission means.

Senders categorized messages by precedence (routine, priority, immediate, flash) to ensure timeliness of transmission. Routine data messages supporting logistics operations soon suffered timeliness delays, attributed to operational headquarters traffic where "50 percent of messages were immediate or flash."[146] The abuse of precedence codes may have reflected a user's attempt to influence the priority of his own information requirements in a switched system where the user had no other direct control measure available to him. Similar evidence of headquarters efforts to retain control of information links appeared in the gradual loss of telephone trunks (or lines available for common use) in favor of sole-user links meant to support point-to-point

[143] Ibid., 250. II Corps expanded from its organic 4th Infantry Division and 1st Cavalry Division by accepting control of the separate 73rd Airborne Brigade, 196th and 199th Light Infantry, and 11th Armored Cavalry.
[144] Ibid., 252.
[145] Rienzi, 89.
[146] Ibid., 91.

combat operations requirements. By April 1968, 85 percent of circuits had been taken over by sole-user requirements.[147]

Vietnam provided a complex environment in which to test new technologies including troposcatter, automatic switching, and satellite communications. Widely dispersed users and the inability to secure land lines of communication did not obviate the need for strategically placed but operationally expensive communications relays. Van Creveld cites the complexity of the political environment and the internal logistics organization as symptoms of inadequate information support. Increased capacity in switched systems allowed new phenomena of message precedence and classification abuse, demonstrating how actual system performance might be worse than having dedicated lines for selected users.[148] Demand for information services continuously exceeded capacity, "[which] proved the self-defeating nature of centralization; the more one tries to achieve total certainty, the greater the increase in the information flow needed to run the operation, and therefore the more uncertain the final results."[149]

Across the Globe, Falklands 1982

The Falkland Island conflict between Great Britain and Argentina in 1982 demonstrated the extreme operational reach provided by advancing communications satellites. Argentina invaded the Falkland Islands, where a British garrison was stationed, on 2 April 1982.[150] As tensions rose just prior to the invasion, the extreme distance of 8,000 miles from the Falklands to Great Britain was considered, and

> Two days before the invasion, a SATCOM [satellite communications] detachment had been given the mission of providing a tactical satellite terminal in the Falklands to improve communications between the Governor and the United Kingdom. However, by the time they arrived on Ascension Island the invasion had already begun.[151]

---

[147] Ibid., 38.

[148] Van Creveld, 247. According to Van Creveld, centralized logistics commands stemmed from Westmoreland's prior decision to sacrifice the division's organic logistic capability for a more rapid deployment and a later inability overcome the initial decision.

[149] De Landa, 79.

[150] Warner, 182.

[151] Ibid., 185.

The Ascension Islands served as intermediate staging base for the naval expeditionary force. The main force headquarters remained aboard the HMS Fearless, which provided a floating base of information with satellite communications.[152] The 3d Commando Brigade, Royal Marines conducted an amphibious landing at Ajax Bay and within a day the satellite detachment had established a link to the United Kingdom from the brigade maintenance area. The shore-based satellite terminal provided responsive communications.[153]

As the force moved east across the Falkland Islands toward the airport at Stanley, units effectively masked their movements using radio silence, lifting it only upon enemy contact. When rugged terrain degraded the effectiveness of FM radios, units then lifted radio silence on the longer range but less secure HF radios.[154] To extend the line of information, radio relays were air-lifted to critical high ground position along the avenue of advance because of the threat posed by bypassed forces.

The rapid pace of the Falklands conflict demonstrated the ability of satellite technology to maintain the same mobility as the deploying force. However, a backlog of messages caused by the overuse of high precedence levels indicated that additional means of communication would be required to support more sustained operations.[155] Overall, the triad of the strategic command in the United Kingdom, the HMS Fearless floating command element, and the ground operational base at Ajax Bay formed a rudimentary base of information, linked by space-based satellites, from which the decisive maneuver advanced over a thin line of information relying on HF radio.

Lateral Communications, Grenada 1983

Operation Urgent Fury, the October 1983 invasion of Grenada, demonstrated a speed of operations similar to the Falkland conflict, but with added complexity due to changes in technology, an airborne operation, and a convoluted task organization. Vice Admiral Josef

[152] Ibid., 189.

[153] Julian Thompson, *No Picnic: 3 Commando Brigade in the South Atlantic 1982* (London: Leo Cooper, 1985; Reprint London: Butler and Tanner, Ltd, 1985), 80.

[154] Warner, 189.

[155] Ibid., 198.

Metcalf commanded the Joint Task Force 120 (JTF-120), composed of a naval carrier battle group, the 82d Airborne Division task force, a marine amphibious unit, and special operation forces including elements from Delta Force, Seal Team 6, and two Ranger battalions.[156] Although each service component deployed with the latest communications systems available, the lack of a joint communications plan precluded interoperability between components.[157] The naval forces provided a mobile base of information with regional satellite connectivity back to the United States. However, the Rangers deployed without in-flight satellite communications before their airborne assault and had to scramble to adjust to mission changes as they arrived within range of the objective.[158]

Operations ashore on Grenada reverted to independent actions because of "poor to nonexistent direct radio communications between 82d Airborne, the Marines, and Metcalf on the Guam."[159] The 82d Airborne Division's light deployment required vehicles be left behind. Since divisional long-range radios were truck-mounted, no long-range communications were available to support ground operations.[160] During one assault, no compatible means of communications existed between supporting artillery and the assaulting force.[161] These and other interoperability challenges would provide focus for joint communications planning over the next decade.

Lessons of Space and Silicon

From Vietnam to Grenada, the communications satellite became the information umbilical between deploying forces. Troposcatter radio and unique VHF radio "bounce" effects extended the electronic lines of information over mountainous terrain. The proliferation of

---

[156] Joint Chiefs of Staff, *Joint Military Operations Historical Collection* (Washington DC: U.S. Government Printing Office, 1997), III-4.

[157] Raines, 394.

[158] Joint Chiefs of Staff, *Joint Military Operations Historical Collection*, III-7.

[159] Mark Adkin, *Urgent Fury: the Battle for Grenada* (Lexington, MA: Lexington Books, 1989), 221.

[160] Ibid., 222.

[161] Joint Chiefs of Staff, *Joint Military Operations Historical Collection*, III-10.

smaller, more capable radios not only increased the information flow at tactical levels, but also revealed new vulnerabilities in communications security. Bases of information began to capitalize on rudimentary data transfer and efficient electronic switching to effectively move information.

Chapter Five

Digital Wars

Metcalf's Law and the Power of Networks

As computer processing power began doubling every eighteen months according to Moore's prediction, data communications also grew exponentially, from the early experimental Advanced Research Projects Agency computer network to the modern Internet.[162] Robert Metcalfe, founder of 3Com Corporation, remarked that the power of networked computers equaled the square of the number of users.[163] In *Out of Control,* Kevin Kelley noted the paradox that network logic is counterintuitive: adding nodes to a network can actually decrease the total distance of wire used for connection up to thirteen percent, but "adding routes to an already congested network will only slow it down."[164]

Tactical communications began to reflect the confluence of computer and network technology. Digital transmission systems supplanted analog systems. Computer systems required increased data connectivity to interoperate. Dedicated data links competed with common-user data service. With this evolution, did computers and digital communications effectively support command and control systems during operational maneuver?

Digital Communications

Information Preparation, Just Cause, Panama 1989

Operation Just Cause saw resolution of most of the information support shortfalls uncovered in Grenada. XVIII Airborne Corps began planning in August 1989 to serve as a joint task force with the mission to remove Panamanian leader General Manuel Noriega from power.[165] The force consisted of the 82d Airborne Division under MG James Johnson, 7th Infantry Division

---

[162] Brian Nichiporuk, Carl H. Builder, and United States. Army, *Information technologies and the future of land warfare* (Santa Monica, CA: Rand Arroyo Center, 1995), 21.

[163] Downes and Mui, 24.

[164] Kevin Kelly, *Out of control : the rise of neo-biological civilization* (Reading, Mass.: Addison-Wesley, 1994), 27. Kelley cites the work of Frank Hwang and Ding Zhu Du at Bell Laboratories for the network length portion, and "Braess's Paradox," the 1968 discovery of Dietrich Braess.

[165] Joint Chiefs of Staff, *Joint Military Operations Historical Collection*, IV-1.

(Light), Marine Corps 2d Light Armored Infantry Battalion, air force and special operations units. Also, the 193rd Infantry Brigade was already stationed in Panama.[166]

Unlike Grenada, signal units had the benefit of interior access to Panama with the presence of the 1109th and 154th Signal battalions providing strategic and tactical communications to forces stationed in country. The 35th Signal Brigade deployed a three-man radio team in November 1989 to evaluate "test shots of potential combat locations."[167] Joint communications plans addressed frequencies and communications security to ensure joint interoperability.

As the operation commenced on 20 December, 1989, the 82d Airborne used en route satellite communications to maintain situational awareness.[168] Air inserted radio teams provided initial communications to command posts. For more communications capacity, the division airlifted the previously deployed radio relay team from Fort Clayton to the tactical operations center at Tocumen International Airport.[169] To support the displacement of the division tactical operations center from the airport to Fort Amador, signal elements had to replicate all communications services at the alternate location by consolidating assets and deploying more systems from Fort Bragg.

Communications success in Panama reflected lessons learned in Grenada. The robust base of information provided by long established military presence in the region significantly enhanced operations. Careful planning and the use of satellite communications established a line of information capable of successfully supporting the airborne insertion, establishment of initial headquarters, and eventual movement to operational locations.

Big Blue Arrows, Desert Storm 1990

Iraq's invasion of Kuwait in August 1990, started a chain of events that culminated in the last great land battle to this day. United States Central Command, responsible for the Southwest

---

166 Ibid., IV-6.

167 Campbell Cantelou, "Jumping into Just Cause," *Army Communicator* 15, no. 1 (Winter/Spring 1990): 7

168 Joint Chiefs of Staff, *Joint Military Operations Historical Collection*, IV-8.

169 Cantelou, 10.

Asia (SWA) geographic area of operations, took command of a rapidly expanding multi-national coalition force. Army Central Command (ARCENT), or Third Army, would serve a triple role as army component command, theater army, and field army headquarters responsible for operational planning for two corps and associated support units.[170]

United States Army, Information Systems Command (Central Area) had been maintaining strategic communications in the cities of Riyadh and Dhahran, Saudi Arabia in support of the US Military Training Mission, via a troposcatter link from Dhahran to the island of Bahrain connected to a large capacity satellite system.[171] Theater communications were gradually expanded from the two initial leased telephone and record traffic circuits to the "largest common-user data communications network ever present in a theater of operations."[172] The scope of the deployment caused the intermingling of five generations of communications equipment, from the manual analog systems of Vietnam brought by some National Guard units, to the most modern Mobile Subscriber Equipment (MSE) that had just been fielded to four army signal battalions. The echelons above corps level Tri-Service Tactical System (TRITAC), installed to support the theater communications network, interfaced most readily with joint and army systems.[173]

The initial deployment of XVIII Airborne Corps in August relied on organic analog communications systems.[174] As forces deployed, the signal plan called for maximum use of digital communications to minimize interoperability challenges. Theater level communications were provided by the Joint Communications Support Element, the Air National Guard's 281st Combat Communications Group, and the Army's 11th Signal Brigade.[175] In addition, by September 1991, leased commercial satellite access provided another ninety-six data channels.[176]

---

[170] John R. Brinkerhoff, *The Signal Support Dilemma: The 335th Signal Command*, ed. Ted Silva and John Seitz, United States Army Reserve in Operation Desert Storm (Washington, DC: Headquarters, Department of the Army, 1994), 3.

[171] Emily Pace, "USAISC Before, During, and After Desert Storm," *Army Communicator* 16, no. 3 (Summer 1991): 13 Bahrain site was operated by a detachment of 11th Signal Brigade.

[172] Raines, 102.

[173] Brinkerhoff, 13.

[174] Ibid., 20.

[175] Ibid., 22.

[176] Wrenne Timberlake, "ISC Takes Desert by Storm," *Army Communicator* 16, no. 2 (Spring

VII Corps deployed from Germany as the decisive force to defeat Iraqi forces in Kuwait.[177] The 93rd Signal Brigade "confronted the challenge of keeping the communications system in step with the anticipated lightning speed maneuvering of the VII corps."[178] Long distances required heavy reliance on satellite and troposcatter radio.[179] The corps took ninety-six hours to develop a stable base communications network.

The 141st Signal Battalion, First Armored Division, operated analog communications systems. According to battalion operations officer, Major Wayne White,

> Because of the speed and scope of the plan and the [commanding general's] intent, the battalion knew that there was no way to maneuver ACSs [Area signal centers] to keep systems on the air as the division advanced. Any attempt to do so would have left the battalion in the dust of the division's charge right from the time most units would cross the line of departure.[180]

To support the operational advance, the battalion abandoned the area communications system concept and dedicated all assets to meeting the commander's information needs. The open terrain allowed the signaleers to attach antennas directly to the sides of the vehicle shelters, drastically reducing installation time during operational pauses.[181] A single multichannel satellite system moved with the division tactical operations center to maintain connectivity with corps main headquarters. The satellite quickly provided critical intelligence and logistical information until a terrestrial link could be established back to the logistics base. On 24 February 1991, the rapid pace of operations prevented the signal support from providing anything more than local links between division main, the tactical command post and the brigade headquarters during four operational halts.[182]

1991): 17

177 Adolph Carlson, "A Chapter not yet Written: Information Management and the Challenge of Battle Command," in *Sun Tzu and information warfare: a collection of winning papers from the Sun Tzu art of war in information warfare competition*, ed. Robert E. Neilson (Washington, DC: National Defense University Press, 1997), 109.

178 Carol E. Stokes and Kathy R. Coker, "Getting the Message Through in the Persian Gulf War," *Army Communicator* 17, no. 1 (Summer-Winter 1992): 20.

179 Ibid., 21.

180 Wayne M White, "Eye of the Storm: Communicating on the Move," *Army Communicator* 16, no. 3 (Summer 1991): 35.

181 Ibid., 36.

182 Ibid., 37.

The 143rd Signal Battalion, Third Armored Division, had finished fielding the new MSE communications in Germany. In training, the battalion had practiced signal support to a "division movement to contact covering 100 kilometers at a rate of 20 miles per hour."[183] The exercise had revealed that positioning equipment on high terrain allowed MSE radio links to operate farther than the design criteria, allowing more forward positioning of communications nodes along the line of advance. Despite the extended planning ranges, the signal platoons could not install the forward nodes fast enough to maintain coverage of advancing maneuver elements. The operational plan for the division during Desert Storm called for a 150-kilometer movement to contact and hasty attack. To support this rapid maneuver, signal support planners devised a scheme to "daisy-chain" communications nodes every thirty kilometers along the line of advance starting with a secure base of two nodes at the division assembly area.[184] Only the division main, the tactical command post, and the division support command would be provided tactical cellular telephone service using the MSE Remote Access Units (RAU).

Full-scale rehearsals of the plan revealed that "installation times had to get faster and that the RAU coverage had to be improved."[185] Execution of the plan succeeded in maintaining a thin thread of connectivity despite General Norman Schwarzkopf's decision to “change the operation from ‘deliberate operations to a pursuit.’”[186] The prior rehearsals and procedures allowed the battalion to adjust the plan to support dynamic tactical actions.

Operation Desert Storm allowed units six months to establish a robust communications infrastructure. Demand for information services exceeded capacity at every echelon, location, and time.[187] Similar to Vietnam, switched systems invited precedence abuse on telephone connections and message traffic, leading to backlogs of information and degraded support.[188] Data transfer

[183] Bryan S. Goda and Robert M. Prudhomme, "Supporting 3rd Armored Division: Communications on a Mobile Battlefield in a 100 hours war," *Army Communicator* 16, no. 2 (Spring 1991): 42.
[184] Ibid., 43.
[185] Ibid., 44.
[186] Carlson, 113.
[187] Stokes and Coker, 20.
[188] Center for Army Lessons Learned, *Joint Tactical Communications*, vol. 92-1 (Fort

systems, including air picture data links, were not sufficiently robust. Outages at critical nodes were difficult to recover.[189]

After action reviews determined that long-range radio extension to support division and corps operations was inadequate to maintain desired redundancy.[190] The transition to offensive operations had quickly outpaced the ability of most communications systems to support the rapid advances into Iraq and Kuwait.

> General Schwarzkopf's maneuver known as the "Hail Mary" displayed the unprecedented ability of large forces to displace over great distances at speeds that outpaced the enemy's ability to react. Field headquarters must not only plan and conduct these rapid operations but also physically move with them.[191]

Strategically, satellite requirements outpaced the ability of the space segment to provide support, causing the full utilization of all available military and commercial systems, and even the costly repositioning of a satellite in orbit, to provide additional coverage.[192]

Digital Computer Networks in War

Digital Wilderness, Somalia 1992

On December 3, 1992, the United Nations Security Council authorized the use of force to "provide security for humanitarian relief efforts in Somalia."[193] The United States Marine Corps' 1st Marine Expeditionary Force deployed as a Joint Task Force from late 1992 to May 1993 and led a "multinational coalition of 20 countries . . . [with] as many as 49 different U.N. and humanitarian relief agencies--none of which was obligated to follow military directives."[194] The 10th Mountain Division deployed as the army component centered on its 2nd Infantry Brigade.

Leavenworth, KS: US Army Combined Arms Center, 1992), 7.

[189] Ibid., 9.

[190] Ibid., 6.

[191] James K. Morningstar, "Technologies, Doctrine, and Organization for RMA," *Joint Force Quarterly*, no. 15 (1997): 39

[192] Jennifer L. Napper, "The Command and Control of Communications in Joint and Combined Operations" (Thesis, Ft. Leavenworth, KS: U.S. Army Command and General Staff College, 1994), 60.

[193] Defense Information Systems Agency, *DISA Grey Beard Panel: Lessons Learned Operation Restore Hope* (Washington, DC: Defense Information Sysems Agency, 1993), 4-1.

[194] C. Kenneth Allard and National Defense University Press., *Somalia operations lessons learned* (Washington, DC: National Defense University Press, 1995), 29.

Within the first few weeks of deployment, the Joint Communications Support Element (JCSE) tactical satellite systems became the critical long-range communications mechanism between extremely dispersed operational areas.[195] Naval forces maintained satellite connectivity afloat to provide an initial base of information. Arriving forces had to deal with a semi-permissive airstrip, small port capacity (one ship at a time), and poor infrastructure and roads. Many of the JTF headquarters and units established operations in the city of Mogadishu due to limited fixed facilities at the airport and seaport. Military tactical satellite teams provided external communications for voice and data circuits to strategic gateways at Fort Meade and Camp Buckner, as well as "reachback" links to Central Command at Macdill Air Force Base, Florida.[196] A mix of digital communications systems (joint, Army, and Marine Corps) established a convoluted but effective base of information ashore.

Expansion of security to the major interior relief centers occurred during the last two weeks in December. JCSE satellite systems traveled with Marine and Army combat forces to secure the southern port of Kismayo and the town of Baledogle along the major line of communication inland. Somalia operations had lower priority of communications support than did concurrent operations in Saudi Arabia. Somali terminals were required to use the Indian Ocean reserve satellite, which had such perturbations in its orbit that tactical satellite antennas struggled to maintain contact.[197] The initial data and voice connectivity was quickly saturated with information demands until a commercial satellite system could be installed.

The final phase of operations expanded security to the remaining humanitarian relief sectors further from Mogadishu, which required additional communications. Satellite terminals provided the range and responsiveness necessary to connect remote sites initially. Delays in deployment of replacement means pinned satellite systems to operational areas through February 1993, longer than anticipated. Arriving troposcatter radio systems, with a 150-mile

[195] Defense Information Systems Agency, 4-1.Period covered 9 –16 Dec 1992.
[196] Viall, 74.
[197] Department of Defense, *C4ISR Handbook for Integrated Planning* (Arlington, VA: OASD(C3I), C4I Integration Support Activity, 1996).

planning range, gradually replaced satellite terminals to interconnect most of the remote locations from the central hub of Mogadishu. Satellite systems then were able to support ongoing missions, including engineer road construction inland from Kismayo, and nondoctrinal operations of small infantry units "more than 50 miles from their headquarters."[198]

For increased communications capabilities, the JTF and the Army component both contracted separately for commercial satellite terminals, over which numerous voice trunks and specific data circuits were installed. Commercial satellite telephones (INMARSAT) provided initial communications to dedicated operational users, primarily telephone service with limited facsimile and electronic file transfer.[199] Since Somalia had no telephone infrastructure, military and civilian users employed an estimated 200 INMARSAT satellite telephones for additional communications.[200]

Dedicated (sole-user) circuits interconnected most data systems in theater with higher command systems in the strategic information base. Derogatorily considered "stove-pipe" systems, they provided an effective way to ensure access for critical systems but were an inefficient use of available bandwidth. Joint communications plans did not require access to unclassified electronic mail, but the 11th Signal Brigade deployed and installed a Mobile Gateway Van to provide an electronic mail host and connection to the military unclassified Internet. Tactical users connected personal computers to a modified tactical telephone and dialed into the unclassified network.[201]

A study of operational communications support in Somalia concluded that the divisional signal battalion requires substantial augmentation to support the division, both in planning expertise in joint task force communications, and in additional satellite terminals and high

[198] Allard and National Defense University Press., *Somalia operations lessons learned,* 78. Troposcatter terminals were the TRC-170(V)2 tropospheric scatter radio system.

[199] Department of Defense. INMARSAT stands for International Maritime Satellite, developed initially as a consortium of countries to establish satellite telephone coverage primarily for ships at sea.

[200] Defense Information Systems Agency, 4-4.

[201] Ibid. Tactical Terminal Adapter provided a computer connection.

capacity telephone switches.[202] Communications helped "overcome some of the inherent difficulties of ensuring that unity of effort, if not command, was being exercised."[203] Service component interoperability had improved since Grenada with digital systems, but planners encountered challenges at the seams between digital networks.

Digital Swarm, Haiti 1994

Operation Uphold Democracy aimed to remove the regime of Raoul Cedras from power after he refused to accept election results in Haiti in 1994. The XVIII Airborne Corps formed the nucleus of the Joint Task Force (JTF-180) that would conduct a forced entry into Haiti. JTF-180 would then transition responsibility to the 10th Mountain Division, formed as another joint task force (JTF-190) to conduct stability operations.

The naval command ship, USS Mount Whitney, provided a floating headquarters with high capacity satellite links providing voice, data, and video teleconferencing. The aircraft carriers USS America and USS Eisenhower conveyed Army brigades and used satellite communications while afloat. The naval expeditionary force use of satellite lines of information "significantly enhanced the control of units and flow of information in all directions.[204] Army communications, innovatively placed aboard the Mount Whitney, provided voice and data communications to Army systems.

JTF-180 airborne forces en route to Haiti connected to each other with line-of-sight radios and to distant headquarters using satellite radio. The strategic base at Atlantic Command and Fort Bragg remained in contact with the floating headquarters aboard the USS Mount Whitney and the airborne elements.[205] When President Carter gained Haitian Leader Cedras's

---

[202] Tim Petit, "Army Divisional Signal Battalion as the Foundation for Support in Military Operations Other Than War" (Student Monograph, Naval War College, Newport, RI, 1997).

[203] Allard and National Defense University Press., *Somalia operations lessons learned,* 77.

[204] 10th Mountain Division, *Operation Uphold Democracy: Operations in Haiti, Planning, Preparation, Execution August 1994 through January 1995* (10th Mountain Division, 1995), 23, CD-ROM.

[205] Robert S. Ferrell, "Operation Uphold Democracy: Contingency Communications and Forced Entry Operations for Haiti," *Army Communicator* 20, no. 1 (Winter 1995): 11.

agreement to leave power, President Clinton cancelled the forcible entry operation, and tactical satellite provided the mechanism for recall of airborne forces.[206]

With transition to permissive entry, effort turned to establishing a robust base of information in Port Au Prince, Haiti. The USS Mount Whitney anchored one mile from shore allowing remote cellular phone coverage to the initial landing at Port Au Prince.[207] The JTF froze electronic security keys during early operations to ensure communications, and also established air courier between headquarters elements.[208] The simultaneous deployment of two JTF headquarters

> resulted in the only systems initially on the ground being a fragile single channel TACSAT capability. The assault CP (JTF 190) arrived late on 19 September and by early morning 20 September MSE connectivity was established to JTF 180, USACOM and the rear.[209]

The airport and seaport facilities around Port Au Prince hosted deploying units and a base of information grew within the city. In some cases, units had to wait three to five days after their arrival before receiving their dedicated communications systems.[210] Mountainous terrain and the eighty-mile distance between Port Au Prince and the northern port of Cap Haitian required satellite connectivity to establish a line of information.[211] Single channel satellite supported over twelve commands spread across the large area.[212] The 10th Mountain Division communications

[206] Walter E. Kretchik, *Invasion, intervention, "intervasion": A concise history of the U.S. Army in Operation Uphold Democracy* (Fort Leavenworth, Kan.: U.S. Army Command and General Staff College Press), CD-ROM.

[207] Center for Army Lessons Learned, *Operation Uphold Democracy: Initial Impressions, D-20 to D+40*, vol. I (Fort Leavenworth, KS: US Army Combined Arms Center, 1994), 23.

[208] Center for Army Lessons Learned, *Operation Uphold Democracy: Initial Impressions, D-20 to D+150*, vol. II (Fort Leavenworth, KS: US Army Combined Arms Center, 1995), 17.

[209] 10th Mountain Division, "Operation Uphold Democracy: Slide Presentation and After-Action Report" (CD-ROM, Ft Drum, NY: Headquarters, 10th Mountain Division, 1995), 17-10.

[210] Center for Army Lessons Learned, *Operation Uphold Democracy: Initial Impressions, D-20 to D+40*, 30.

[211] 10th Mountain Division, "Operation Uphold Democracy: Slide Presentation and After-Action Report", 17-8.

[212] 10th Mountain Division, *Operation Uphold Democracy: Operations in Haiti, Planning, Preparation, Execution August 1994 through January 1995*, 23.

plan also allocated MSE to infantry battalion level because of a "high probability that their maneuver battalions would be located by themselves in remote enclaves, beyond FM range."[213]

Haiti operations also highlighted the extension of computer networks to the tactical level. The military's secret data network connected major headquarters and allowed computer systems such as the Global Command and Control System (GCSS) to share information. The operation demonstrated the first use of the tactical secret data network (Tactical Packet Network, or TPN), with seventeen computers connected in Haiti, thirteen on the Mount Whitney, and a few at the strategic base at Fort Bragg. Interconnection of the two secret networks at the reachback node at Fort Bragg allowed secret data communication from infantry battalion to strategic U.S. headquarters although the number of connections was limited due to concern over bandwidth limitations if the terminal pool had expanded.[214] Unclassified data requirements drove the deployment of a special Mobile Gateway Van (using a commercial leased circuit) to provide electronic mail and logistics, finance, and personnel data.

Lessons of Digital Wars

Digital communications provided great advantages in capacity, clarity, and capability to military forces. Coupled with increased ability to move large amounts of information between units, the computer provided an information explosion that caused a conflict between voice, data, and message systems. Signal units employed innovative methods to meet requirements with ad hoc organizations.[215] As demand exceeded capacity, signal planners prioritized information

---

[213] Center for Army Lessons Learned, *Operation Uphold Democracy: Initial Impressions, D-20 to D+40*, 48.

[214] Ibid., 34.

[215] Ralph I. Jr. Ebener, "Operational Communications: What Does it Take?" (Monograph, School of Advanced Military Studies, Command and General Staff College, 1995), 20.

support during movement to critical command information. Intuitively, one can infer that the quest for information today would result in the same exponential increase in demand for capacity during future operations.

Chapter Six

Transformation and the Future of Information

Big Blue Arrows and Information

The battlefield information superiority dilemma has been examined by tracing the impact of advancing technology levels on information support during operational movement. A marked contrast has existed between the level of information support built up over time at a base of operations and the level of support that could be extended along lines of information in support of forces in motion. In *Men Against Fire,* S.L.A Marshall noted the effect of battle on information:

> The flow of men and materiel during battle is ever toward the front. The flow of orders and instructions is toward the front. But the prevailing flow of information, on which the writing of orders and instructions for combat are based, is ever toward the rear, and the volume of it seems to increase according to the square of the distance from the fighting line.[216]

Marshall's observation could be predictive of future digital networks envisioned for the transformation force. One recent command post exercise in Korea

> . . . demonstrated that ample information can be generated. As in other commands, the concern is differentiating between the relevant and irrelevant. Using the critical requirements of the commander as a filter, C4I architecture can be manipulated to deselect information irrelevant to effective and timely decision making.[217]

The future quest for information must be tempered by digital discipline and focused on relevant information to determine the best method of transmission.

The Army's modernization plans for tactical communications include the Warfighter Information Network-Tactical (WIN-T) system as the objective communications system.[218] WIN-T design places a heavy reliance on reducing the number of different equipment types to a single base line of equipment. Transformation calls for increased reliance on communications satellites to provide for the extended ranges projected between command posts. Transformation

[216] S. L. A. Marshall, *Men against fire : the problem of battle command in future war* (Gloucester, Mass.: Peter Smith, 1978), 100.

[217] Tilelli, 80.

[218] Jeffrey Smith, "Warfighter Information Network-Tactical: the Army's Vision," *Army Communicator* 24, no. 2 (Spring 1999). [Online] Accessed 9 May 2000. available from http://www.gordon.army.mil/regtmktg/AC/SPR99/win-t.htm.

will also extend the tactical Internet throughout the battle space to concentrations of friendly forces.[219]

History demonstrates that each new level of technology provided benefits and limitations to lines of information. Transformation forces will be able to effectively leverage lines of information to support maneuver if the maneuver elements consider the operational reach of information as an element of combat power and take positive steps to resource the line of information. However powerful the new applications of technology, the fundamental constraints of line-of-sight radio propagation, bandwidth of radio links, and capacity of satellite systems will still apply. Overcoming the increased friction of war inherent in movement may entail deliberately withholding information systems support to less critical locations or functions on the battlefield to provide an information reserve that can respond to the unforeseen demands of maneuver.

Evolution of Lines of Information

Big blue arrows in the Civil War ebbed and flowed along the rail lines. Signal flags and field telegraphs extended the lines of information from the telegraph network to the fighting force. The Spanish American war began the expeditionary involvement of the United States off the North American continent and the search for secure military lines of information, first demonstrated by the submarine cable, now graduated to high-capacity satellite. Satellite support evolved from tenuous links in Vietnam to high-capacity backbone links during Desert Storm and Uphold Democracy.

World War I communications demonstrated the limitations of the telegraph and telephone to support the German advance into France. The new dimension of wireless telegraphy provided new ways to overcome the frailty of wire over short distances. A sharp line divided the information support in the trenches from that available “over the top” during an offensive. World

[219] Rick Makowski, "EPLRS-More than Just data," *Army Communicator* 15, no. 1 (Winter/Spring 1990)

War II operations demonstrated the utility of the electromagnetic spectrum to pass multiple channels of voice and data over a single radio link. Radio technology extended to deeper echelons encountered interoperability problems that units could only overcome with organizational changes. Korea communications highlighted the importance of remote hilltops to provide radio relay over rugged terrain. Relay teams became critical assets and important targets for enemy forces.

Vietnam communications demonstrated the utility of tropospheric radio and satellite communications. Wire systems could not provide secure lines of information in an insurgency environment. The speed with which the Falklands and Grenada operations transpired precluded wire communications. Wire communication provided the internal lines of information in each conflict, allowing mobile radio systems to remain available to support the movement to the next phase of the operation. British forces in the Falklands with standard radio systems did not suffer the same level of interoperability problems that US forces encountered with different generations of joint communications systems in Grenada.

Panama communications demonstrated the benefit of interior lines of information with signal elements able to conduct electronic reconnaissance of the proposed combat area. Airborne communication maintained a secure line of information to the strategic base. Future operations in Haiti coupled the same airborne communications capability with links to JTF command ships en route to the objective area.

Desert Storm communications demonstrated the difference between analog and digital systems during initial deployment and subsequent operations into Iraq. The reach of the lines of information could not keep pace with the movement of forces in most cases, causing short gaps in information support. Similar speed of operations in Somalia outpaced the deployment of terrestrial troposcatter radio systems, requiring the use of numerous satellite systems. Mobility of information systems matched the pace of the force in motion only with satellite communications.

The proliferation of smaller, more capable radios increased the information flow at tactical levels. New radios revealed vulnerabilities in the survivability of information, leading to improvements in communications security. Increased density of radio systems also provided inherent redundancy to recover from sudden, catastrophic loss of key information nodes.

Bases of information began to capitalize on rudimentary data transfer and efficient electronic switching to move information. Digital communications provided increased capacity, clarity, and capability to military forces. The computer provided information storage and processing power that further strained the capacity of interconnecting lines of information. Dedicated computer links ("stove-pipes") competed with common-user telephone lines and other message transfer systems. Integrated networks compiled larger numbers of computer systems that competed for information flow within their own virtual network. As more users gained access to new communications systems, information flow expanded in unexpected ways as the complexity of the information system increased. In *Out of Control,* Kevin Kelley observed that

> The only way to make a complex system that works is to begin with a simple system that works. Attempts to install a highly complex organization . . . without growing it, inevitably leads to failure. . . . Time is needed to let each part test itself against all the others. Complexity is created, then, by assembling it incrementally from simple modules that can operate independently.[220]

Operational Considerations for Lines of Information

Deployment to conflicts often provides the first "big blue arrow" with the added confusion of complex task organizations. Existing information support plans seldom can envision every complexity of organizational design. After Operation Restore Hope, Kenneth Allard recommended that commanders "organize JTF Headquarters in modules, each with its associated logistics and communications, and to deploy them in successive stages as capabilities are added to the force." [221] Selection of the commanding headquarters for an operation must consider the

> . . . [command and control (C2)] capabilities of a joint force commander and his staff and their envisioned role in the operation; who has the leading capability to plan and execute a mission and/or the preponderance of forces operating in the medium; . . .what is the

[220] Kelly, 469.
[221] Allard and National Defense University Press., *Somalia operations lessons learned,* 42.

> interoperability of C2 and the forces involved; what span of control does the C2 architecture allow; and what is the duration and scope of operations?[222]

High ground became critical for radio relay in World War II and remains important today. From Vietnam to Haiti, the communications satellite became the new high ground, providing the information pivot between deploying forces and their strategic base. Joint doctrine recommends the use of satellite only if terrestrial radio systems cannot be employed, reserving satellites for "those critical situations where no other means can fulfill the requirement."[223] General Howell Estes, Commander of Space Command, confirmed that

> Satellite communications . . . are the lifeline of military operations. They are critical where there is inadequate infrastructure . . . to provide more information to lower command levels. Because of expanding demands for support, we expect a blend of military, civil, commercial, and international systems to meet our future satellite communications needs.[224]

Sustaining information flow requires an emergence of stability from complex systems interaction. In *The Technology Trap,* Timothy Garden addressed the limitations of each military communication system:

> The VHF and UHF bands have the advantages of offering reliable communications with high data density, but can only do this over line of sight orders of range. . . . The use of land-based relay stations, while effective, is costly and makes any network vulnerable. The use of airborne relay systems extends range, but requires constant patrol of relay aircraft. Space-based satellite relay is the obvious choice for providing long-range reliable communications . . . however the vulnerability of satellites in the future suggest that it would be unwise to rely exclusively on such systems.[225]

Garden's analysis supports the thesis that it would be unwise to expect to maintain information superiority without leveraging the complementary strengths and weaknesses of each means of communication. Early attempts at digitizing the force have not demonstrated

---

[222] Charles C. Krulak, "Knowledge Based Warfare: A Security Strategy for the Next Century," *Joint Force Quarterly*, no. 14 (1996): 22.

[223] Joint Chiefs of Staff, *Joint Doctrine for Employment of Operational/Tactical Command, Control, Communications, and Computer Systems*, Joint Publication 6-02 (Washington D.C.: U.S. Government Printing Office, 1996), 2-8.

[224] Howell M. III Estes, "Space and Joint Space Doctrine," *Joint Force Quarterly*, no. 14 (1996): 62. General Estes served as Commander in Chief of United States Space Command

[225] Timothy Garden, *The technology trap : science and the military*, 1st ed. (London ; Washington: Brassey's Defence Publishers, 1989), 96.

overwhelming improvements. However, the experiments provide a digital laboratory for the emergence of effective means to integrate complex technologies in support of maneuver.[226]

Previous management of data systems as individual circuits, while inefficient from an overall systems perspective, limited the impact of one system on the operation of another. Digital indiscipline by information consumers can lead to increased demands for capacity similar to the imprecise metrics applied by communications planners in Vietnam. Consequently, common user data networks, such as the tactical packet network, must balance minimum connectivity for all members with assured access for high priority information flow. Naveh's dynamic of the operational and tactical pivot of information demonstrated one potential friction point between the information demands of different commanders.

Logistics planning provides the closest parallel from which to examine the idea of information culmination. Joint doctrine for operations states that a key element of operational campaign design is operational reach bounded by logistics. Planners must consider

> That logistics fixes the operational reach of combat forces—the distance over which military power can be concentrated and employed decisively. It can extend operational reach by forward basing, transport, effective lines of communication, and throughput of supplies.[227]

Logistics plans revolve around "information and technological solutions that place the right logistics in the right place at the right time."[228] Doctrine explains the difference between a unit's required supply rate and the commander's controlled supply rate as means for weighting ammunition flow to the expected main effort. Commanders need an equivalent "controlled information rate" that focuses the line of information where most needed since "it is no longer sufficient to simply establish communications and automation links . . . [commanders] must recognize and act to minimize inherent vulnerabilities in systems."[229] Points of information

[226] Karen L Sinclair, "Information and the Future of Battle Command" (Thesis, Ft. Leavenworth, KS: U.S. Army Command and General Staff College, 1996), 30.

[227] Kevin R. Wheelock, "Review Criteria for the Logistics Plan," *Joint Force Quarterly*, no. 15 (1997): 131

[228] Dennis J. Reimer, "Leaping Ahead to the 21st Century," *Joint Force Quarterly*, no. 17 (1998): 21

[229] Brian E. Fredericks, "Information Operations at the Crossroads," *Joint Force Quarterly*, no. 16

culmination appear when the lines of information cannot match the force's tempo or cannot provide redundancy to pass critical information despite the friction of combat.

Conclusion

Future forces must plan lines of information to focus support where most needed. Without digital discipline, military information networks tend to overload weak links at the expense of important information. Satellite communications and digital computer networks provide great capabilities for transformation forces. However, fundamental constraints still exist in line-of-sight radio propagation, communications channel capacity, and network congestion.

The passage of time during operational pauses allows information support to grow in redundancy and survivability. Movement negates many of the advantages that accrue from stability and the information support during movement diminishes based on distance and speed. To ensure information superiority at critical times during the operational maneuver, transformation forces must coherently apply all means of information transfer to extend the line of information through achievement of the next objective.

(1997): 100

Appendix

Principles of Command and Control as Evaluation Criteria

Principles	Joint Publication 6-0	Win-T Performance Criteria[230]	Selected Criteria
Interoperability	Ability to share information among different users or services: related to commonality, standardization, liaison	The Network must interoperate with service-specific, Joint, Coalition, and commercial networks (Critical Information Exchange first, then *All requirements)*	(Built into design of systems)
Flexibility	Meet changing circumstances with minimum of disruption or delay		
Discipline	Information network controlled, technical and spectrum direction, and focused with CCIR and other procedures to provide priority	Network Management Must exchange critical network configuration management info with the Joint Network Management System and manage network performance	(Related to Responsiveness during operational movement)
Responsiveness	Respond rapidly to warfighter needs for information: Reliable, redundant, timely		* Especially challenging during movement
Mobility	Systems must be as mobile as the forces they support		* Direct reflection on movement
Survivability	Security provided by dispersion, multiplicity, and hardening. Includes passive measures, emission control	Network must support tactical operations with multiple transmission paths, terrestrial and satellite; automatic routing around congestion or failure; simultaneous transmission of voice, data, and video (eventually to *Include airborne transmission paths)* Transport Data utilizing NSA approved security mechanisms at different security classification levels without any likelihood of intermixing the data	* Challenged during movement by increased exposure to enemy forces, less redundancy, and increased need for security.
Sustainability	Must provide continuous support during any type or length of operation: consolidation of like services, integration of means, use of commercial where practical		* Easier sustainability during pauses, harder to maintain while moving

[230] Thomas E. Taylor and Edward Siomacco, "Warfighter Information Network-Tactical (Win-T)" (Briefing, Department of the Army, Force Development, 2000).

Bibliography

Books

Addington, Larry H. *The patterns of war since the eighteenth century.* 2nd ed. Bloomington: Indiana University Press, 1994.

Adkin, Mark. *Urgent Fury: the Battle for Grenada.* Lexington, MA: Lexington Books, 1989.

Alberts, David S., John J. Gartska, and Frederick P. Stein. *Network Centric Warfare: Developing and Leveraging Information Superiority*. Washington, DC: C4ISR Cooperative Research Program, 1999.

Alexander, E.P. *Military Memoirs of a Confederate*. New York: Charles Scribner's Sons, 1912.

Allard, C. Kenneth. *Command, control, and the common defense*. New Haven: Yale University Press, 1990.

Allard, C. Kenneth, and National Defense University Press. *Somalia operations lessons learned.* Washington, DC: National Defense University Press, 1995.

Appleman, Roy Edgar. *Disaster in Korea: The Chinese Confront MacArthur*. College Station, TX: Texas A&M University Press, 1989.

Army War College (U.S.). *The Signal Corps and Air Service. A study of their expansion in the United States, 1917-1918* Monograph no. 16. Washington, DC: Govt. Print. Off., 1922.

Barnett, Correlli. *The Swordbearers; Studies in Supreme Command in the First World War.* London: Eyre & Spottiswoode, 1963; Reprint Indiana: Indiana University Press, 1975.

Bates, David Homer. *Lincoln in the Telegraph Office: Recollections of the United States Military Telegraph Corps During the Civil War.* New York: The Century Co., 1907.

Bergen, John D. *Military Communications: A Test for Technology* United States Army in Vietnam. Washington, DC: Center of Military History, United States Army, 1986.

Beuche, Frederick J. *Introduction to Physics for Scientists and Engineers*. Third ed. New York: McGraw Hill, 1980.

Brinkerhoff, John R. *The Signal Support Dilemma: The 335th Signal Command* United States Army Reserve in Operation Desert Storm, ed. Ted Silva and John Seitz. Washington, DC: Headquarters, Department of the Army, 1994.

Brown, Joseph Willard. *The Signal Corps, U.S.A. in the War of the Rebellion*. Boston: U. S. Veteran Signal Corps Association, 1896.

Bucholz, Arden. *Moltke, Schlieffen, and Prussian War Planning.* Providence, RI: Berg Publishers, 1991; Reprint Paperback, 1993.

Carlson, Adolph. "A Chapter not yet Written: Information Management and the Challenge of Battle Command." In *Sun Tzu and information warfare: a collection of winning papers from the Sun Tzu art of war in information warfare competition*, ed. Robert E. Neilson, 103-124. Washington, DC: National Defense University Press, 1997.

Cohen, Eliot A., and John Gooch. *Military misfortunes : the anatomy of failure in war*. New York: Free Press, 1990.

Coker, Kathy R. , and Carol E. Rios. *A Concise History of the Signal Corps*. Fort Gordon, GA: United States Army Signal Center and Fort Gordon, 1988.

Crowell, Benedict. *America's Munitions 1917-1918*. Washington, DC: Government Printing Office, 1919.

De Landa, Manuel. *War in the age of intelligent machines*. Swerve ed. New York: Zone Books, 1991; Reprint Cambridge, Mass: MIT Press, 1994.

Devereux, Tony. *Messenger Gods of Battle: Radio, Radar, Sonar, the Story of Electronics in War*. New York: Brassey's (UK), 1991.

Downes, Larry, and Chunka Mui. *Unleashing the killer app: digital strategies for market dominance*. Boston: Harvard Business School Press, 1998.

Fuller, W.G. "The Corps of Telegraphers under General Anson Stager During the War of Rebellion." In *Sketches of War History 1861-1865*, II. Cincinnati: Robert Clarke & Co., 1888.

________. "Reminiscences of the Signal Service in the Civil War." In *Personal Narratives of Events in the War of the Rebellion*, VIII. Providence, RI: Rhode Island Soldiers and Sailors Society, 1899.

Garden, Timothy. *The technology trap : science and the military*. 1st ed. London ; Washington: Brassey's Defence Publishers, 1989.

Greely, A. W. *Reminiscences of adventure and service; a record of sixty-five years*. New York: Charles Scribner's Sons, 1927.

Griffin, Gary B. *The Directed Telescope: A Traditional Element of Effective Command*. Fort Leavenworth, KS: Command and General Staff College, 1991.

Harley, William B., and Hale Mason, eds. *History of the 57th Signal Battalion Word War II: February 10, 1941 to September 29, 1945*. New York, 1984.

Ignatieff, Michael. *Virtual war : Kosovo and beyond*. New York: Henry Holt, 2000.

Infantry Journal. *Infantry in Battle*. Second ed. Washington, DC: The Infantry Journal, Incorporated, 1939; Reprint U.S. Army Center for Military History, 1997.

Jomini, Antoine Henri. *Jomini and his Summary of the art of war.* Translated by J.D Hittle. Vol. 2, Roots of Strategy. Mechanicsburg, PA: Stackpole Books, 1987.

Keegan, John. *The Face of Battle*: The Viking Press, 1976; Reprint New York: Penguin Books, 1978.

Kelly, Kevin. *Out of control : the rise of neo-biological civilization*. Reading, Mass.: Addison-Wesley, 1994.

Korty, L.H. "The Telegraph in the Civil War." In *Civil War Sketches and Incidents*, I. Nebraska: Commandery of the State of Nebraska, 1902.

Krepinevich, Andrew F. *The Army and Vietnam*. Baltimore: Johns Hopkins University Press, 1986.

Kretchik, Walter E. *Invasion, intervention, "intervasion": A concise history of the U.S. Army in Operation Uphold Democracy*. CD-ROM. Fort Leavenworth, Kan.: U.S. Army Command and General Staff College Press, 1999.

Leonhard, Robert R. *Fighting by minutes : Time and the Art of War*. Westport, Conn.: Praeger, 1994.

Malvino, Albert P. *Electronic Principles*. Third ed. New York: McGraw Hill, 1984.

Marshall, S. L. A. *Men against fire : the problem of battle command in future war*. Gloucester, Mass.: Peter Smith, 1978.

Millett, Allan R. "Cantigny, 28-31 May 1918." In *America's First Battles, 1776-1965*, ed. Charles E. Heller and William A. Stoft., 81-108. Lawrence, KS: University Press of Kansas, 1986.

Moore, Harold G., and Joseph L. Galloway. *We were soldiers once -and Young: Ia Drang, the battle that changed the war in Vietnam*. 1st ed. New York: Random House, 1992.

Myer, Charles R., and United States. Dept. of the Army. *Division-level communications, 1962-1973*. Washington, D.C.: Government Printing Office, 1982.

Naveh, Shimon. *In pursuit of military excellence : the evolution of operational theory* The Cummings Center series . 7. London ; Portland, OR: Frank Cass, 1997.

Nichiporuk, Brian, Carl H. Builder, and United States. Army. *Information technologies and the future of land warfare*. Santa Monica, CA: Rand Arroyo Center, 1995.

Plum, William R. *The Military Telegraph During the Civil War of the United States*. Chicago: Jansen, McLurg & Company, 1882; Reprint Lacrosse, WI: Northern Micrographics, Inc., 1998.

Price, Alfred. *The History of U.S. Electronic Warfare*. Westford, MA: The Association of Old Crows, 1984.

Raines, Rebecca Robbins. *Getting the message through : a branch history of the U.S. Army Signal Corps* Army historical series. Washington, D.C.: Center of Military History U.S. Army, 1996.

Rienzi, Thomas G. *Communications-Electronics, 1962-1970* Vietnam Studies. Washington, DC: Department of the Army, 1972.

Roberston, W. Glenn. "First Bull Run, 19 July 1861." In *America's First Battles, 1776-1965,* ed. Charles E. Heller and William A. Stoft., 81-108. Lawrence, KS: University Press of Kansas, 1986.

Ryan, Michael, and Michael Frater. *A Tactical Communications Systems for Future Land Warfare*. Working Paper 109 ed. Australia: Land Warfare Studies Centre, 2000.

Scriven, George Percival. *The service of information, United States Army* Circular, no. 8. Washington, DC: Govt. print. off., 1915.

Shiflet, Kenneth E. "Communications Hill in Korea." In *The story of the U.S. Army Signal Corps,* ed. Max L. Marshall, 188-191. New York,: F. Watts, 1965.

Sledge, E. B. *With the old breed, at Peleliu and Okinawa*. New York: Oxford University Press, 1990.

Terrett, Dulany. *The Signal Corps: the emergency (to December 1941)*. Washington,: Office of the Chief of Military History Dept. of the Army, 1956.

Thompson, George Raynor, and Dixie R. Harris. *The Signal Corps: the outcome (mid-1943 through 1945)*. Washington,: Office of the Chief of Military History U.S. Army; [for sale by the Superintendent of Documents U.S. Govt. Print. Off.], 1966.

Thompson, Julian. *No Picnic: 3 Commando Brigade in the South Atlantic 1982*. London: Leo Cooper, 1985; Reprint London: Butler and Tanner, Ltd, 1985.

Toffler, Alvin, and Heidi Toffler. *War and anti-war : survival at the dawn of the 21st century*. Boston: Little Brown, 1993; Reprint Warner Books, 1995.

Van Creveld, Martin L. *Command in war.* Cambridge, Mass: Harvard University Press, 1985.

Warner, Philip. *The Vital Link: The Story of Royal Signals 1945-1985*. London: Leo Cooper Ltd., 1989.

Westover, John Glendower. *Combat support in Korea*. Washington,: Combat Forces Press, 1955.

Electronic Sources

10th Mountain Division. "Operation Uphold Democracy: Slide Presentation and After-Action Report." CD-ROM, Ft Drum, NY: Headquarters, 10th Mountain Division, 1995.

________. *Operation Uphold Democracy: Operations in Haiti, Planning, Preparation, Execution August 1994 through January 1995.*: 10th Mountain Division, 1995. CD-ROM.

Joint Chiefs of Staff. *Joint Vision 2020*. Joint Staff, 2000. Accessed November 3, 2000. Online. Available from http://www.dtic.mil/jv2020/jv2020a.pdf.

The Science of the Transistor. 2000. Accessed 27 November 2000. Online. Available from http://www.pbs.org/ /transistor science.

Shinseki, Eric K. *The Army vision: Soldiers on Point for the Nation . . . Persuasive in Peace, Invincible in War.* 1999. Accessed 12 October 1999. Online. Available from www.hqda.army.mil/OCSA/vision.htm.

Government Documents

Center for Army Lessons Learned. *Joint Tactical Communications*. Vol. 92-1. Fort Leavenworth, KS: US Army Combined Arms Center, 1992.

________. *Operation Uphold Democracy: Initial Impressions, D-20 to D+40.* Vol. I. Fort Leavenworth, KS: US Army Combined Arms Center, 1994.

________. *Operation Uphold Democracy: Initial Impressions, D-20 to D+150*. Vol. II. Fort Leavenworth, KS: US Army Combined Arms Center, 1995.

Defense Information Systems Agency. *DISA Grey Beard Panel: Lessons Learned Operation Restore Hope*. Washington, DC: Defense Information Sysems Agency, 1993.

Department of Defense. *C4ISR Handbook for Integrated Planning*. Arlington, VA: OASD(C3I), C4I Integration Support Activity, 1996.

Headquarters Combined Arms Center. *ARFOR Organization and Operational Concept (Draft).* Headquarters, Combined Arms Center, 2000. Accessed 2 February 2000. Online. Available from FTP://160.149.109.31/TF ARFOR/.

Headquarters Department of the Army. *Information Operations.* Field Manual 100-6. Washington, DC: U.S. Government Printing Office, 1996.

________. *Operations (DRAG Edition)* Field Manual 3-0. Washington, DC: U.S. Government Printing Office, 2000.

Joint Chiefs of Staff. *Doctrine for Command, Control, Communications, and Computer (C4) Systems Support to Joint Operations* Joint Publication 6-0. Washington D.C.: U.S. Government Printing Office, 1995.

________. *Information Operations.* Joint Publication 3-13. Washington D.C.: U.S. Government Printing Office, 1996.

________. *Joint Doctrine for Employment of Operational/Tactical Command, Control, Communications, and Computer Systems* Joint Publication 6-02. Washington D.C.: U.S. Government Printing Office, 1996.

________. *Joint Military Operations Historical Collection.* Washington DC: U.S. Government Printing Office, 1997.

________. *Joint Vision 2010.* Washington, DC: Department of Defense, 1997.

Articles

Armitage, Richard Lee, Andrew F. Krepinevich, and Others. "National Security in the 21st Century: The Challenge of Transformation." *Joint Force Quarterly*, no. 16 (1997): 15-19.

Cantelou, Campbell. "Jumping into Just Cause." *Army Communicator* 15, no. 1 (Winter/Spring 1990): 6-11.

Casper, Lawrence E., Irving L. Halter, and others. "Knowledge Based Warfare: A Security Strategy for the Next Century." *Joint Force Quarterly*, no. 13 (1996): 81-89.

Cohen, William S. "Report of the Quadrennial Defense Review." *Joint Force Quarterly*, no. 16 (1997): 8-14.

Estes, Howell M. III. "Space and Joint Space Doctrine." *Joint Force Quarterly*, no. 14 (1996): 60-63.

Ferrell, Robert S. "Operation Uphold Democracy: Contingency Communications and Forced Entry Operations for Haiti." *Army Communicator* 20, no. 1 (Winter 1995): 7-14.

Fredericks, Brian E. "Information Operations at the Crossroads." *Joint Force Quarterly*, no. 16 (1997): 97-103.

Goda, Bryan S., and Robert M. Prudhomme. "Supporting 3rd Armored Division: Communications on a Mobile Battlefield in a 100 hours war." *Army Communicator* 16, no. 2 (Spring 1991): 42-47.

Halloran, Joe. "Command and Control Interoperability." *Military Review* 66, no. 10 (October 1986): 38-49.

Hoffman, F.G. "Joint Vision 2010: A Marine Perspective." *Joint Force Quarterly*, no. 17 (1998): 32-38.

Krulak, Charles C. "Knowledge Based Warfare: A Security Strategy for the Next Century." *Joint Force Quarterly*, no. 14 (1996): 20-23.

Makowski, Rick. "EPLRS-More than Just data." *Army Communicator* 15, no. 1 (Winter/Spring 1990): 12-16.

Mehaffy, Michael. "Vanguard of the Objective Force." *Military Review* 80, no. 5 (September-October 2000): 6-16.

Morningstar, James K. "Technologies, Doctrine, and Organization for RMA." *Joint Force Quarterly*, no. 15 (1997): 37-43.

Murray, Williamson. "Thinking About Revolutions in Military Affairs." *Joint Force Quarterly*, no. 16 (1997): 69-76.

Pace, Emily. "USAISC Before, During, and After Desert Storm." *Army Communicator* 16, no. 3 (Summer 1991): 13-17.

Reimer, Dennis J. "Leaping Ahead to the 21st Century." *Joint Force Quarterly*, no. 17 (1998): 20-24.

Smith, Jeffrey. "Warfighter Information Network-Tactical: the Army's Vision." *Army Communicator* 24, no. 2 (Spring 1999) Accessed 9 May 2000. Online. Available from http://www.gordon.army.mil/regtmktg/AC/SPR99/win-t.htm.

Stokes, Carol E., and Kathy R. Coker. "Getting the Message Through in the Persian Gulf War." *Army Communicator* 17, no. 1 (Summer-Winter 1992): 17-25.

Stokes-Rios, Carol E. "MacArthur Relied on the Signal Corps." *Army Communicator* 13, no. 4 (Fall 1988): 16-17.

Tilelli, John H. Jr. "Putting JV 2010 into Practice." *Joint Force Quarterly*, no. 17 (1998): 76-80.

Timberlake, Wrenne. "ISC Takes Desert by Storm." *Army Communicator* 16, no. 2 (Spring 1991): 16-18.

Wheelock, Kevin R. "Review Criteria for the Logistics Plan." *Joint Force Quarterly*, no. 15 (1997): 128-133.

White, Wayne M. "Eye of the Storm: Communicating on the Move." *Army Communicator* 16, no. 3 (Summer 1991): 34-37.

Unpublished Works

Ebener, Ralph I. Jr. "Operational Communications: What Does it Take?" Monograph, School of Advanced Military Studies, Command and General Staff College, 1995.

Napper, Jennifer L. "The Command and Control of Communications in Joint and Combined Operations." Thesis, Ft. Leavenworth, KS: U.S. Army Command and General Staff College, 1994.

Nowowiejski, Dean A. "Concepts of Information Warfare in Practice: General George S. Patton and the Third Army Information Service August-December, 1944." Monograph, School of Advanced Military Studies, 1995.

Petit, Tim. "Army Divisional Signal Battalion as the Foundation for Support in Military Operations Other Than War." Student Monograph, Naval War College, Newport, RI, 1997.

Sinclair, Karen L. "Information and the Future of Battle Command." Thesis, Ft. Leavenworth, KS: U.S. Army Command and General Staff College, 1996.

Taylor, Thomas E., and Edward Siomacco. "Warfighter Information Network-Tactical (Win-T)." Briefing, Department of the Army, Force Development, 2000.

Viall, Kenneth E. "Medium Brigade 2003: Can Space-based Communications Ensure Information Dominance?" Thesis, Ft. Leavenworth, KS: U.S. Army Command and General Staff College, 2000.