



55th Signal Company, Combat Camera (Kyle Davis)

BLACK LIGHTS:

Chaos, Complexity, and the Promise of Information Warfare

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Arthur Clarke, a science fiction writer, stated that any sufficiently advanced technology is indistinguishable from magic. Although his point may be quaint it bears directly on the debate over the revolution in military affairs (RMA), which is long on description and short on explanation of future military technology. This is most evident in the promised wizardry of information warfare.

The magical quality of information warfare stems from a vague understanding of the nature of information itself. Since rational discussion is predicated on the explanatory power of carefully chosen conceptual terminology, the RMA debate can be furthered only to the extent that the issues are viewed from a common framework. Such a critical perspective allows one to see the true limits and powers of information warfare. At the

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 1997		2. REPORT TYPE		3. DATES COVERED 00-00-1997 to 00-00-1997	
4. TITLE AND SUBTITLE Black Lights: Chaos, Complexity, and the Promise of Information Warfare				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Defense University, 260 Fifth Ave SW, Fort Lesley J McNair, Washington, DC, 20319				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

same time a closer look at information helps clarify two questions central to this debate: How do information technologies create a revolution in the means and methods of waging war? What objective criteria can help measure such revolutionary change?

Information and Control

Information and control represent two sides of the same coin. However, the discussion of information invariably neglects the control relationship. Control is regulating influence directed at some predetermined goal. It thus consists of two elements: the regulating influence of one agent or actor over another in that the former causes change in the behavior of the latter; and purpose in that influence is guided toward a prior objective set by the controlling agent. Since leadership provides purpose, direction, and motivation it is easy to see the important role that the military leader plays in the control and regulation of forces.

The notion of control exists on all levels of human activity and forms the basis of society. The primordial urge to dominate and regulate both nature and the environment puts control at

the center of the evolutionary spiral. Domination over nature was realized through technology that put man on a path from the stone axe to the supercomputer. The ability to produce and use

tools such as the axe changed human thought. As described by Burke and Ornstein, the “axe-making ability to do things in the proper order is one of the brain’s many natural talents.” Indeed, they describe it as the whole foundation of planning and problemsolving:

... the axemaker talent for performing the precise, sequential process that shaped axes would later give rise to the precise, sequential thought that would eventually generate language and logic and rules which would formalize and discipline thinking itself. The newly dominant sequential talent of the mind was able to use the “cut-up-nature-and-control-it” capability to extract more knowledge from the world and then use that knowledge to cause further change. Thanks to the axemakers’ talents and their gifts, things literally would never, at any time, be the same.¹

The domination of nature through all aspects of technology brought change and difference to the forefront of control. The idea that two things are recognizably different or that things change over time is key to the theory of control—cybernetics—and the etymology of *control*, a term which comes from the Latin *contrarotulare*, meaning to mark similarities and differences. That

changes and differences can be determined through comparison creates an inseparable link between control and information. Control develops information in two reciprocal ways. First, because control is goal-directed there must be a continuous comparison between the current and intended state. This ongoing comparison generates feedback to the controlling agent. Second, the controller engenders information in the form of adjustment instructions that feed forward to the controlled agent.

In warfare armies ultimately seek to dominate and control enemies by destroying their will. This struggle for control creates feedback information, as the status of armies is in constant flux. Staffs continuously process information and assess situations vis-à-vis overall mission objectives. Commanders feed forward information as “fragos” or other forms of instruction. The feedback of information as intelligence about self and enemy and the feedforward of information as instruction completes the reciprocal cycle of control. It is only through the process of control that information has meaning or indeed objective existence. Fundamentally, then, the object of information warfare is to destroy the ability of an enemy to control while protecting one’s own.

Crisis and Revolution

Recognizing the relationship between control and information provides a perspective from which to regard RMA. The present revolution is a military expression of the latest information revolution. James Beniger has argued that this current upheaval is the fourth to occur. According to his view the natural evolution of living systems like armies creates a crisis in control. That crisis is resolved only after a sudden transformation in information processing and communication—an information revolution. The first crisis occurred four billion years ago as the issue of controlling reproduction arose. DNA—a complex macromolecule deoxyribonucleic acid with programming, decision, and control apparatus—became the first information revolution and resolved the crisis. It “organizes matter and energy at the most fundamental level of control [and is] not only the most basic of all control technologies . . . but also one whose capabilities are unlikely to be rivaled by technologies of our own making for many generations to come.”² DNA is the basic building block of all genetic material. A one-inch strand holds as much information as 12,000 typed pages or twenty 500-page books. The nucleus of a single human cell contains five feet of genetic code, equivalent to 2,000 such books. DNA information

the present revolution is a military expression of the latest information revolution

is structured to provide feedforward executive control over human life by shaping and organizing it. Soldiers constitute the basic genetic material in a combat organization. Education, training, and doctrine are military DNA that forms warriors and thus shapes the Armed Forces.

The second control crisis emerged 600 million years ago when living things began to move through space and time. It was resolved by an information revolution that resulted in the brain and central nervous system. Chemistry dominated life processes for four billion years until

entire feedforward-feedback cybernetic loop that was swift, clear, and reliable. Command and staff processes are basically poor models of the brain and nervous system. Evolution of the brain led to modern war and human society, thus creating a third control crisis.

Genetic control via DNA programming does have one shortcoming: the genetic blueprint is virtually fixed forever. The encoded information cannot be reprogrammed, but roughly 120,000 years ago humans began to reprogram themselves through the use of technology. Beginning with the rapid development of simple tools they were able to extend natural capabilities and circumvent their hardwired genetic code. By 10,000 B.C. the swift development of tools led to a crisis in the control of new technology and induced a third information upheaval, the agricultural revolution. In addition to the five basic mechanical tools—lever, wheel, pulley, screw, and wedge—cultural tools such as alphabets, numbers, laws, money, organized armies, towns, and states emerged to extend and enhance natural capabilities. The agricultural revolution culminated with the rise of civilization which was, in effect, a control system that sought to regulate four tasks. First, governance by a central government—normally headed by a king—integrated society through a feedforward system of laws. A primitive bureaucracy afforded feedback control. Second, security provided by armed force protected the state and its interests. The first RMA arose out of this development. Third, logistics through an economic system ensured relative efficiency in the extraction, processing, and distribution of scarce resources. Fourth, science—embodied initially in priests—ultimately sought to understand the world and extend human fitness beyond nature by new advances in technology. At the basis of this revolution was an increasingly homogeneous society bound together by verbal and written flow of information. At the same time writing and simple arithmetic provided requisite information processing capabilities to guide civilization to its next control crisis.

Black Light

This term refers to the invisible or “black” portion of the electromagnetic spectrum which is the domain of x-rays and radio waves. “Black lights” is used in another sense, however. In boxing a fighter may receive a hard shot to the head that causes a knockout. Some boxers report seeing “black lights” before they sink into oblivion: they see and become surrounded by a shimmering, glowing aura of darkness that is referred to in medical terminology as a “visual scotoma.” The boxers are experiencing the paradox of being conscious of their unconsciousness. The reason for this phenomenon is that when the higher cognitive centers of the brain shut down, the lower areas, called the limbic system, kick in and preserve a primitive sense of awareness. Thus a kind of self-organization occurs among human systems in the same ways armies undergo self-organization after the initial clash of arms. Air theorists such as John A. Warden III and David A. Deptula develop an argument for “parallel warfare” that is based on a fundamental disregard of the ability of a military system to self-organize at lower echelons of command. The ability for self-organization greatly limits the practical utility of so-called parallel warfare. See John A. Warden III, “The Enemy as a System,” *Airpower Journal*, vol. 9, no. 1 (Spring 1995), pp. 41–55; David A. Deptula, “Firing for Effect,” *Defense and Airpower Series* (Arlington, Va.: AEF, August 24, 1995); and Michael E. Ruane, “Wisdom of ‘Smart’ Bombs Still Debated,” *Philadelphia Inquirer*, August 14, 1996, pp. 1, 3.

primitive electronics became important when creatures began to stir. “The first electronic systems possessed by primitive animals were essentially guidance systems, analogous logically to sonar or radar.”³ The brain and nervous system had two advantages. First, the brain provided executive control that feedforwarded information in a dynamic lethal environment. It also lent a staff control function that rapidly assessed information feedback from the outside world. Second, the electronic-based nervous system provided an

Lightning in the Wires

For over 10,000 years civilization moved along at the pace of a walking man. Information travelled at the same speed. During this period the extension of human natural fitness had reached its limit inherent in existing technology. The constraint was that tools and toolmaking relied upon muscle power. However, technological advances during the Enlightenment replaced simple tools with complex machines which were characterized by the use of inanimate sources of power.

The steam engine was the first child of the industrial revolution. That advance, rather than

Combined arms
exercise at
29 Palms, California.



USS Key West.



U.S. Navy (James W. Olive)

2^d Marine Division, Combat Camera (E.J. Young)

being a revolution in its own right, was really a crisis of control. Since machines did not require muscle power, they were no longer controlled directly by a human hand. As a consequence whole elaborate control systems had to be developed to master machines, and thus cybernetics was born. “Gritty steam engines, not teeny chips, hauled the world into the information age.”⁴ Machines like the steam engine were quickly integrated into complex systems such as railroads. Because of their distributed nature and speed they had to be controlled in new ways. Just as nature resolved its second control crisis with an electronic-based nervous system, civilization resolved this new crisis with a similar electronic innovation—the telegraph.

The influence of the telegraph was profound. In one stroke it dealt with the problem of distributed control—mastering segmented cellular agents and activities separated by vast distances in space and time. For billions of years this problem prevented single-cell organisms from being networked into multifunctional distributed organisms. As with the nervous system electricity held the key. In the human body nerve tissue can sustain an information signal at 260 miles per hour, fast enough to regulate and control distributed agents like arms and legs and activities like digestion and reproduction.⁵ Degrade this flow of information appreciably and death follows inevitably. Similarly the telegraph was able to network society, economic markets, government bureaucracies, and distributed military formations because information was able to move unambiguously, reliably,

and swiftly. Of these, speed was the most important factor and established a quantitative milestone for the magnitude of the current information revolution.

Equating Information and Energy

In 1905 Albert Einstein formulated his theory on the relationship between mass and energy. We can postulate a similar relation between energy and information beginning with the seemingly trivial observation that no two objects can occupy the same space at the same time, a fundamental characteristic of mass. Similarly no two bits of information can occupy the same space at the same time; thus information has the physical dimension of mass.⁶ This relationship suggests two basic and revolutionary implications for any rigorous theory of information warfare. First, as a form of mass, information flows. Second, the speed of its transmission marks a revolutionary

break with all forms of regulation and control prior to the middle of the 19th century.

The emergence of electricity as the primary means of regulation and control radically altered the physical characteristics of living organisms and human organizations. Before electricity these systems were characterized by their solidity:

dense, segmented, cellular, and monolithic. A dense, solid system was controlled by information collected, processed, and distributed in a sequential and linear manner. In the

military sphere armies behaved in a way described by the laws of solid mechanics. The so-called Lanchester equations, for example, are mathematical analogs for torque and linear force,

key elements of solid mechanics.⁷ Dense monolithic armies were controlled and regulated by the discrete and sequential movement of the written and verbal word. Armies fought in a manner described by Soviet military theorist G.S. Isserson as the “strategy of a single point.”⁸ They collided like huge bowlingballs on small point-like battlefields. Electronic-based control and regulation gave rise to parallel distributed information networks which could provide a continuous flow of information. Coincident with the development of black light (electromagnetic) technology, battlefield lethality grew markedly and led to a phenomenon known as the “empty battlefield”—the massive dispersal of troops across an ever expanding area.⁹

The use of railroads in preparing and mobilizing for war followed a distributed pattern that coincided with the parallel configuration of rail networks and urban grids. As warfare became total it became protracted. Militaries had to defend—and conquer—resource, agricultural, and industrial areas distributed throughout the depth of warring nations. The dense, solid pre-industrial military forces began to disaggregate and be distributed to accommodate physical characteristics of modern nation-states. Fundamentally, armies began to liquefy and flow to give rise to a basic characteristic of operational art: distributed deep maneuver. In this the continuous and fluid nature of electronic communications made operational art possible. Indeed the emergence of operational art is the first essential stage in the current RMA.

The last few paragraphs discussed the material character—the statics—of information and the armies it regulated. The continuous distributed nature of information supplanted the discrete, concentrated form. Information and armies coevolved, which imparted to military art a much more fluid quality ultimately revolutionizing the dynamics of war. In a fundamental way the physics of fluidity overturned the physics of solidity.

Another feature of mass is its ability to move through space and time. The most significant aspect of the control crisis and information revolution is the speed with which information was able to move. Only through the near-light speed of networked information can continuous control and regulation of distributed forces be maintained. Imagine, for example, the brain controlling limbs and life processes like digestion at the speed of a traveling horse: distributed control and regulation would be impossible and life would cease. Today, for instance, the continuous fluid and wavelike nature of lightning-fast information can control and regulate all aspects of full spectrum dominance as outlined in *Joint Vision 2010*.

dense monolithic armies were controlled by the discrete movement of the written word

The Telegraph

Although it may strike us as obvious now, it took a long while for the world’s best inventors to transpose even the simplest automatic circuit such as a feedback loop into the realm of electronics. The reason for the long delay was that from the moment of discovery electricity was seen primarily as power and not as communication. The dawning distinction of the two-faced nature of the spark was acknowledged among leading German electrical engineers of the last century as the split between the techniques of strong current and the techniques of weak current. The amount of energy needed to send a signal is so astoundingly small that electricity had to be reimagined as something altogether different from power. In the camp of the wild-eyed German signalists, electricity was a sibling to the speaking mouth and the writing hand. The inventors (we would call them hackers now) of weak current technology brought forth the most unprecedented invention of all time—the telegraph. With this device human communication rode on invisible particles of lightning. Our entire society was reimagined because of this wondrous miracle’s [wireless] descendants.

—Kevin Kelly, *Out of Control*



28th Public Affairs Detachment (William Cronk)



M-1 tank during Advanced Warfighting Experiment.



F-117 Stealth fighters.

115th Mobile Public Affairs Detachment (David Burkle)

U.S. Air Force (Marvin Lynchard)

years—theorists have yet to recognize the exquisite complexity of modern military systems. Complexity is:

*a characteristic of systems made up of more than two elements, suggesting intricacy of structure and process, but not randomness, sometimes with a high degree of regularity in their dynamics up to a point of transition; usually implying a reasonable degree of predictability and controllability, which may quickly pass through a state-change into what is or seems to be chaos, such as the effect of a single accident on rush-hour traffic, the outbreak of a riot in a crowd or prison, or the political upheaval in Eastern Europe in 1989 flowing out of long maintained stable states.*¹⁰

In a complex system:

*a great many independent agents are interacting with each other in a great many ways. . . . The very richness of these interactions allows the system as a whole to undergo spontaneous self-organization. . . . These complex, self-organizing systems are adaptive, in that they. . . actively try to turn whatever happens to their advantage. . . . Every one of these complex, self-organizing adaptive systems possesses a kind of dynamism that makes them qualitatively different from static objects. . . . Complex systems are more spontaneous, more disorderly, more alive. . . . Each of these systems is a network of many “agents” acting in parallel. . . . The control of a complex adaptive system tends to be highly dispersed. . . . A complex adaptive system has many levels of organization. . . . [They] are constantly revising and rearranging their building blocks as they gain experience. . . . All complex adaptive systems anticipate the future. . . . They are active. . . . It’s essentially meaningless to talk about a complex adaptive system being in equilibrium: the system can never get there. It is always unfolding, always in transition.*¹¹

The new fluid quality of information in support of operational art, expressed vividly in the control and regulation of distributed deep maneuver, fundamentally changed the physical character of warfare. The movement and flow of distributed mass armies and networked information often manifested a state of turbulence, eddies of disorganization and disorder that for the first time in the history of the art of war transformed the simple dense monolithic tactical structures into distributed complex operational organizations fighting at the edge of chaos.

Control at the Edge

The current RMA, which began in the last century, has led to the emergence of complexity as the defining characteristic of modern military organizations and operations. While complexity theory developed—especially over the last ten

Complexity is a spontaneous consequence of imposing regulation and control on a highly distributed, fluid, chaotic state. Remove control in the military—the flow of information—and the force loses its cohesion and disintegrates. Because of its energy equivalence information performs a control function directly analogous to the effect of a magnetic field on a pile of metal filings. The magnetic field shapes the filings the way information shapes an organization. The velocity of the magnetic flux approaches the same speed of light as information moving through a communication network. The density and velocity of information flow objectively measures the complexity of an organization.

From the foregoing discussion it appears that complexity has a number of dimensions, but all of them ultimately turn on the way a complex

dynamic system uses information. A military system uses information five ways. The first is the way it describes itself and its enemy. The more information required the more complex the description. Second, a complex military system uses information to organize itself. Indeed, it is the energy aspect of information that forces and shapes an organization into a particular structure. Third, after the industrial revolution armies became algorithmically complex: the number of tasks or steps necessary to defeat an enemy grew dramatically. There is evidence of this in the rapid increase in the size of planning staffs beginning with the American Civil War and the increasingly protracted nature of modern war. The emergence of operational art in this period is another consequence of the algorithmic complexity of conflict. Wars could no longer be won with a few battles. Instead, commanders and staffs had to program and execute a whole mosaic of deep and protracted operations to defeat an adversary. Fourth, the logistics of information—acquisition, processing, and distribution—became complex. It was no longer possible for commanders to sit on horse-

since information has the dimension of mass it must be processed like other resources

back and gaze at battlefields. They and their staffs had to actively seek out information widely distributed across countless battles in deep theaters of operations. Since information has the physical dimension of mass it must be extracted, processed, and distributed like other material resources. In this regard it is like fuel for the mind with a kind of energy or octane rating; the greater the visual content the higher the octane level. The electronic battlefield seeks to provide the same total visual awareness. Because of the refining capacity of the computer, information can be processed to attain the highest level possible in the form of images.

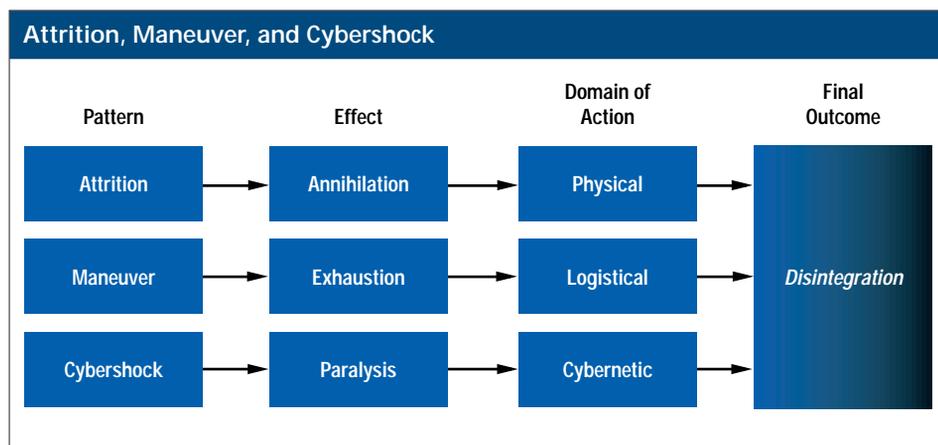
Finally, military technology makes modern forces complex in two ways. In the first place, since machines of the industrial revolution, unlike muscle-driven tools, relied on inanimate forms of energy like coal, steam, oil, and electricity the movement and sustainment of armies in the field drew increasingly on a complex network of distributed continuous logistics. The regulation of this form of logistics drove the information and control needs of modern forces. Second, technology itself is embedded with information. Not only do the new machines become more complex to use and produce, technology carries within itself an increasingly dense and complex pattern of its own evolution. Since technology extends the natural capabilities of humans, it gives them the potential for self-evolution and self-revolution by artificially changing their genetic code. Give a man a rifle and you have extended his natural lethal capability. Through technology humans become the editor and author of their genetic character. Emerging technologies contain all the information of newer, more advanced drafts of previous programs of instruction, which shapes human nature. The self-revolution of black light technology marks the beginning of a new book of evolution that cannot be comprehended with pre-industrial thinking: the grammar, language, syntax, and logic have become too complex. Similarly, wars can no longer be understood, discussed, and waged successfully in terms of this old paradigm. Complex armies inexorably lead to a revolution in the art of war.

Cybershock

Modern armies are complex systems that flow in a sea of information. They rush together like great rivers along wide, turbulent fronts. Destroy that fluid medium and an enemy is frozen and effectively paralyzed. This cybernetic paralysis is the essence of cybershock, the third form of warfare. Until the information revolution the art of war consisted of attrition and maneuver with

attrition leading to annihilation and maneuver to exhaustion. Both forms of warfare were typically applied simultaneously, with attrition -> annihilation favoring the stronger side and maneuver -> exhaustion favoring the weaker. The rise of complex armies created a new array of vulnerabilities that information warfare now seeks to exploit.

Cybershock creates paralysis in five ways. First, through operations security, deception operations, and psychological operations an enemy



is denied complete information of its adversary and itself. Second, electronic warfare destroys enemy coherence and cohesion, basically freezing its nervous system. Third, active and intense reconnaissance and counterreconnaissance on every level blinds an enemy. Fourth, the shock of surprise places a tremendous burden on an enemy's nervous system by creating a general state of panic. Finally, the intensity and rapidity of friendly operations inflicts a kind of cybernetic stupor on an enemy. Ideally paralysis reduces an enemy to its component parts. It would be a serious error, however, to believe that one can defeat an enemy by paralysis alone. Patterns of war are complementary and mutually reinforcing. Their synergism develops an integrated posture of attack and defense meant to destroy complex military systems by attrition, maneuver, and cyber-shock (see figure). The outcome occurs in the moral domain with the disintegration and destruction of the will to fight. Failure to consider modern patterns of war in their totality only leads to defeat. The fact is that military systems are rarely destroyed exclusively by paralysis. As seen earlier one remarkable attribute of complex military systems is that they are spontaneously self-organizing.

A complex system like an army has its intelligence spread throughout itself. In war "each member reacts individually according to internal rules [training and doctrine] and the state of its local environment."¹² Armies in battle have a distributed mind or being that has a swarm or hive-like quality. Sun Tzu, the ancient philosopher of war, noted a similar phenomenon: "In the tumult and uproar the battle seems chaotic, but there is no disorder; the troops appear to be milling about in circles but cannot be defeated. . . . Apparent confusion is a product of good order."

Such ideas highlight an essential quality of modern forces—that overall systemic paralysis and disorganization can be offset to a point by self-organization and reorganization on lower levels of command. Thus militaries have the fractal quality of a *holograph*, a photo taken with laser-light that when shattered into pieces still retains the image of the whole in each fragment. There is thus a distinction between self-organizing military systems and biological systems. For an organism like the human body paralysis is total in the sense that a person with a broken neck does not experience sudden self-organization and spontaneous control of limbs. A joint force, on the other hand, may suffer complete cybernetic collapse—the analog to a broken neck—but spontaneously reorganize at lower echelons and continue with its mission. The efficacy of the German idea of *auftragstaktik* is based on the self-organizing ability of subordinate leaders and units.

The significance of self-organization for information warfare should be evident: destroying a disorganized enemy may depend ultimately on its physical—perhaps protracted—defeat in detail. If an enemy still has the will to fight, its fate will have to be decided with a simple bullet rather than a complicated piece of hardware. Iwo Jima and Okinawa remind us how rare and sweet victories like the Gulf War are. Sleight of hand in technology and information warfare should not conjure up false hopes or visions of future war. At the same time the Armed Forces must unshackle the limits—and challenge the promise—of information war. In the end wars are won by soldiers, not by magicians. JFQ

NOTES

¹ James Burke and Robert Ornstein, *The Axemaker's Gift* (New York: Grosset/Putnam, 1995), p. xvi.

² James R. Beniger, *The Control Revolution* (Cambridge: Harvard University Press, 1994), p. 54.

³ Fred Hoyle, *Man in the Universe* (New York: Columbia University Press, 1964), pp. 24–25.

⁴ Kevin Kelly, *Out of Control* (New York: Addison-Wesley, March 1995), p. 115.

⁵ William F. Ganong, *Review of Medical Physiology*, 8th ed. (Los Altos, Calif.: Lange Medical Publications, 1977), p. 29. I am indebted to Leah J. Stevens for this key insight.

⁶ James Clerk-Maxwell, "Remarks on the Mathematical Classification of Physical Quantities," *Proceedings of the London Mathematical Society*, March 1871, pp. 224–33; D.C. Ipsen, *Units, Dimensions and Dimensionless Numbers* (New York: McGraw-Hill, 1960), pp. 61–63, 131–52; Henry L. Langhaar, *Dimensional Analysis and Theory of Models* (New York: John Wiley and Sons, 1965), pp. 1–11, 60–78; and Robert A. Carman, *Dimensional Analysis* (New York: John Wiley and Sons, 1969), pp. 179–215.

⁷ James J. Schneider, "The Exponential Decay of Armies in Battle," *Theoretical Paper No. 1* (Fort Leavenworth, Kans.: School of Advanced Military Studies, April 23, 1985).

⁸ James J. Schneider, *The Structure of Strategic Revolution* (Novato, Calif.: Presidio Press, 1994), pp. 11–12.

⁹ James J. Schneider, "The Theory of the Empty Battlefield," *Journal of the Royal United Services Institute* (September 1987), pp. 37–42.

¹⁰ Roger A. Beaumont, *War, Chaos, and History* (Westport, Conn.: Praeger, 1994), p. xiv.

¹¹ M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon and Schuster, 1992), pp. 11–12, 145–47.

¹² Kelly, *Out of Control*, p. 22.

This article is an edited and abridged version of an entry that received third prize in the 1996 JFQ "Essay Contest on the Revolution in Military Affairs" sponsored by the National Defense University Foundation.