Chaoplexic warfare or the future of military organization

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Ours is the age of the network. Whether framed in socio-economic, technological or ideological terms, our present times are increasingly seen as characterized by the rise and spread of fluid, decentralized forms of social organization in which information and telecommunication devices play key roles. For Manuel Castells, author of the seminal *Network society* trilogy, the network constitutes nothing less than 'the new social morphology of our societies' whose 'logic substantially modifies the operation and outcomes in the processes of production, experience, power and culture'.[1]

Business enterprises are seen to be moving towards more flexible and open organizational arrangements as they alternately cooperate and compete with other companies on specific projects, flatten their hierarchical structures by cutting out layers of middle management, and outsource and subcontract large areas of their activities in order to increase their reactivity and adaptability to changing economic environments. In many sectors, the large bureaucratic centres of production which once dominated the industrial era no longer appear suited to competing with their more nimble counterparts within a fast-paced global economy.

Within civil society, non-governmental organizations have proliferated, representing a bewildering range of agendas and political stances but capable of forming powerful ad hoc coalitions to lobby, demonstrate and campaign for or against specific issues. The anti- (or alter-)globalization movement has been perhaps the most spectacular manifestation yet of the disparate yet highly effective transnational social groupings, capable of coalescing and acting worldwide without any formal overarching organizational structure, that seem to be eclipsing mass-membership trade unions and political parties as vehicles of social contestation.[2]

In the criminal underworld, the loose confederation of organizations pursuing illicit activities which mushroomed in Russia after the collapse of the Soviet Union inaugurated a broader trend away from large, centralized criminal associations. In the aftermath of the successful dismantling of the Cali and Medellín cartels in the

1 Manuel Castells, *The rise of the network society*, 2nd edn (Cambridge, MA, and Oxford: Blackwell, 2000), p. 500.

2 Mario Diani and Doug McAdam, eds, *Social movements and networks: relational approaches to collective action* (Oxford: Oxford University Press, 2003); Donatella Della Porta, Massimiliano Andretta, Lorenzo Mosca and Herbert Reiter, *Globalization from below: transnational activists and protest networks* (Minneapolis: University of Minnesota Press, 2006).

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1990s, the Colombian drugs trade has shifted towards a decentralized network of several hundred smaller groups, spreading its activities more widely and rendering its operations far less vulnerable to traditional decapitation strikes aimed at taking out key leaders. Likewise, the disruption of the Sicilian Cosa Nostra has seen ownership of the majority of the Italian drug trade pass to the 'Ndrangheta criminal organization from Calabria, which employs a more horizontal structure in which autonomous elements are held together by a common perspective and interests but do not form a single vertical organization.[3]

The internet is of course the most celebrated manifestation of this network era, but we can find a wide array of information and telecommunication technologies and infrastructures deployed within all these burgeoning forms of social organization. Faced with these remarkable transformations occurring across the social field, many now believe with Castells that 'networks are proliferating in all domains of the economy and society, outcompeting and outperforming vertically organized corporations and centralized bureaucracies'.[4]

War is no exception. At the turn of the century, the Pentagon adopted the doctrine of network-centric warfare and set out its vision of autonomous 'swarming' and 'self-synchronized' warfighting units connected to one another by high-speed data links and superior battlefield awareness. Of course, the actors that have truly excelled at adopting loose, decentralized organizational structures are the jihadist networks and insurgent movements that have tied down the net-enabled US army in Afghanistan and Iraq. The recently retired head of US Central Command responsible for operations in the Gulf and Central Asia, General John Abizaid, is in no doubt that 'the enemy is in fact more networked, more decentralized, and operates within a broader commander's intent than any twentieth century foe we've ever met. In fact, this enemy is better networked than we are.' The lesson is clear, however: 'It takes a network to beat a network, and our network must be better.'[5]

The widespread availability of information and telecommunication technologies has no doubt contributed to empowering such organizational arrangements; but is it in itself a sufficient explanation for the present emergence of the network society and its impact on military thinking and practice? While technology certainly contributes to defining the space of possible social formations and practical organizational arrangements, it remains nonetheless primarily a tool which is given meaning and put to specific uses within a broader sociocultural setting. The aeroplane may have made strategic bombing possible, but the latter's implementation required the adoption of a whole set of organizational, tactical and normative commitments. Nor does technology appear *ex nihilo*: it is the product of a particular human engagement with the world. As Martin van Creveld has observed, 'behind military hardware there is hardware in general, and

[3] 'Ancient feuds and new crimes', *GNOSIS* no. 3, 2007, http://www.sisde.it/Gnosis/Rivista12.nsf/ServNavigE/13, accessed 5 Aug. 2008.
[4] Manuel Castells, *The internet galaxy* (Oxford and New York: Oxford University Press, 2001), p. 1.
[5] Arthur K. Cebrowski, speech delivered at 'Transformation Warfare '07', Virginia Beach Convention Center, VA, 20 June 2007.

Table 1: The four regimes of the scientific way of warfare

	Mechanism	*Thermodynamics*	*Cybernetics*	*Chaoplexity*
Key technology	Clock	Engine	Computer	Network
Scientific concepts	Force matter in motion linearity geometry	Energy entropy probability	Information negentropy negative feedback homeostasis	Information non-linearity positive feedback self-organization emergence
Form of warfare	close order drill rigid tactical deployments	mass mobilization motorization industrialization	command and control automation	decentralization swarming

behind that there is technology as a certain kind of know-how, as a way of looking at the world and coping with its problems'.[6]

In the present age, it is science that provides the dominant way of looking at the world, whether as a methodological disposition to problem-solving or in informing our conceptions of how the world works. Our present understanding of the social world in terms of information and networks is directly reflected in the central preoccupations of contemporary science. Indeed, the genealogy of the concepts of swarming and self-synchronization dear to network-centric warfare can be traced back to the scientific theories of chaos and complexity which have emerged over the past few decades. Where technology has played a role, it is in conjunction with the scientific conceptual frameworks that have accompanied its development and diffusion. From the very introduction of the term 'network-centric warfare' in 1998, military doctrine and scientific theory were being explicitly linked by its proponents: 'Military operations are enormously complex, and complexity theory tells us that such enterprises organize best from the bottom-up.'[7]

Nor is this a novel phenomenon. In fact, scientific concepts and theoretical frameworks have been influencing military thought and practice since the inception of the scientific revolution in the late sixteenth century. Moreover, the traffic between science and warfare has not been all one way: military imperatives have stimulated both technological and scientific discoveries. From the earliest synergies between the study of the motion of bodies and military ballistics, science and the military art have been inextricably bound, long before the scientific breakthrough of the Manhattan project yielded the atomic weapon.

This article will argue that a *scientific way of warfare*, understood as the application of the methodological and theoretical frameworks of science to the exercise of military force, established itself at the beginning of the modern era and has since grown in influence to become one of the dominant lenses through which armed conflict is contemplated. Inspired by the formidable successes of modern

[6] Martin van Creveld, *Technology and war: from 2000 BC to the present* (New York: Free Press, 1989), p. 1.

[7] Arthur K. Cebrowski and John J. Garstka, 'Network-centric warfare: its origin and future', *Proceedings of the US Naval Institute* 24: 1, Jan. 1998, pp. 28–35.

technoscience, military men in search of certainty on the battlefield have turned to the intellectual tools that have proved so effective in predicting and dominating the natural world. The specific ideas brought to bear on military affairs have evolved alongside the theoretical developments of science, and four distinct regimes of the scientific way of warfare will be distinguished here: mechanistic, thermodynamic, cybernetic and chaoplexic warfare. Each of these regimes is closely associated to a paradigmatic technology which dominated the contemporaneous historical period both as a tool and as a general explanatory model for the essential workings of the world—respectively the clock, the engine, the computer and the network (see table 1).

The scientific and military quests for order

Throughout the ages, military leaders have sought to organize and direct their armies as to best preserve their order and coherence when faced with the centrifugal forces of chaos unleashed on the battlefield. In this way they have tried to avert for as long as possible the state of disorganized free-for-all which threatens all armies under the stress of battle. The forces that have succeeded in remaining organized while precipitating their adversaries into disarray have almost invariably prevailed.

Hence, for van Creveld,

> the history of command in war consists essentially of an endless quest for certainty—certainty about the state and intentions of the enemy's forces; certainty about the manifold factors that together constitute the environment in which the war is fought, from the weather and the terrain to radioactivity and the presence of chemical warfare agents; and last, but definitely not least, certainty about the state, intentions, and activities of one's own forces.[8]

Likewise, John Keegan notes that the fundamental purpose of training 'is to reduce the conduct of war to a set of rules and a system of procedures—and therefore to make orderly and rational what is essentially chaotic and instinctive'.[9] The practice of warfare can thus be understood as the attempt to impose order over chaos, to exert control where it most threatens to elude, and to find predictability in the midst of uncertainty.

States, along with other political entities, seek to employ organized violence in order to attain certain political objectives. As only one of the instruments of statecraft, rational and measured employment of military force must be commensurate with the overall objective to which it is intended to contribute. This is the meaning of Clausewitz's oft-repeated dictum that war is the continuation of policy by other means, strategic thinking being the exercise of judgement over the appropriate means to be deployed in the pursuit of a given political end. However, the formulation of strategy and the assessment of the role of military force within

8 Martin van Creveld, *Command in war* (Cambridge, MA, and London: Harvard University Press, 2003), p. 264.
9 John Keegan, *The face of battle* (London: Cape, 1976), pp. 18–19.

it require an understanding of the likely effects of any course of action. Hence, for Gray, 'if the essence of strategy is instrumentality, the essence of instrumentality is predictability'.[10] Strategic thought and behaviour are therefore necessarily accompanied by a rationalization of military force as an instrument of broader political objectives and a theorization of the potential and limits of the use of organized violence, all in an effort to bring order and predictability to activities which would otherwise be governed by chance and contingency.

A clear parallel can be drawn between the ordering processes inherent in military organization and the instrumental application of armed force, on the one hand, and scientific endeavour, on the other. Indeed, scientists continuously strive to extract patterns from 'noise', to identify regularities in the fog of randomness, to uncover the 'laws' governing the behaviour of nature and reveal the hidden order behind its apparent chaos. For the scientist Norbert Wiener, the 'highest destiny' of mathematics, the universal language of science, was 'the discovery of order among disorder'.[11] Alfred North Whitehead expressed the same idea, albeit in more poetic fashion, when he proposed that the pursuit of mathematics was 'a divine madness of the human spirit, a refuge from the goading urgency of contingent happenings'.[12]

With the discovery and formulation of regularities comes greater predictability of phenomena and an enhanced control over the natural world, notably through the technical devices assembled to exploit such constancies in nature. Auguste Comte, the founder of positivism, explicitly made this link: 'from science comes prevision; from prevision comes control.'[13] The scientific project is thus inextricably connected to the drive for greater control and power over the world, as originally formulated by one of its earliest expositors, Francis Bacon: *scientia potentia est* ('knowledge is power').

The successes of modern science in uncovering seemingly eternal laws of nature and developing or perfecting technological contraptions to take advantage of them has unsurprisingly proved highly attractive to military thinkers and practitioners seeking to dominate the battlefield and render their activity as predictable as possible. Many, in the image of Jomini, have thus been persuaded that 'all strategy is controlled by invariable scientific principles' only awaiting discovery by the rational mind, and have thus sought to emulate the achievements of the natural sciences.[14] Along with the adoption of a scientific disposition in the study of military problems, the resulting scientific way of warfare has entailed the espousal of the successively dominant theoretical frameworks of the sciences, shaping four distinct orientations to the exercise of armed force throughout the modern era.

10 Colin S. Gray, *Strategy for chaos: revolutions in military affairs and the evidence of history* (London: Cass, 2002), p. 98.
11 Steve J. Heims, *John von Neumann and Norbert Wiener: from mathematics to the technologies of life and death* (Cambridge, MA, and London: MIT Press, 1980), p. 68.
12 Heims, *John von Neumann and Norbert Wiener*, p. 116.
13 Ian T. King, *Social science and complexity: the scientific foundations* (Huntington, NY: Nova Science, 2000), p. 20.
14 John Shy, 'Jomini', in Peter Paret, ed., *Makers of modern strategy from Machiavelli to the nuclear age* (Princeton, NJ: Princeton University Press, 1986), p. 146.

Mechanistic warfare and the clock

Dominant in European thought throughout the seventeenth and eighteenth centuries, the ideas of mechanism constituted the first major body of scientific discourse of the modern epoch. Under it the universe became understood as an entirely mechanical system composed wholly of matter in motion under a complete and regular set of laws of nature. Central to mechanism were the laws of motion as formulated by Newton, the concomitant notions of force, gravity, mass and the reversibility of time, and the belief that any whole could be understood through the analysis of its individual parts.

Within the mechanistic world-view, clockwork acted not only as a model for the order, regularity and predictability of the universe and its diverse natural bodies but also as a mechanism serving scientific enquiry as an instrument and object of study. By embodying a general concept of operation and model of organization enmeshed in wider cultural discourses, clockwork came to represent simultaneously the unveiled order of the physical world and a prescribed ideal in human affairs. Chaos was exorcized by the invocation of divine clockwork behind all phenomena and the promise of complete predictability and control. A clockwork universe also implied a divine watchmaker who had constructed its mechanism and set it in motion. This vision resonated with the enlightened absolutism of the day, its faith in the rational and orderly organization of government, and the position of the monarch as uncontested divine representative and sole seat of power.

Mechanistic warfare subscribed to the same vision, with its armies emphasizing rehearsed, synchronous movements and characterized by the lack of autonomy of their parts and their unflinching obedience to the predetermined sequence of battle decided upon by their commanders. Geometry and the newly discovered laws of motion were widely applied to improve fortifications and ballistics, but in the field the tendency was towards shaping armies into giant clockwork mechanisms. In an age in which the state of firearms technology meant its effects on the battlefield were maximized through coordinated volleys, and with the possibility of communications highly restricted once engagement with the enemy had begun, troops were heavily drilled into marching in step according to rigid tactical deployments and performing synchronized firing and reloading cycles at the highest possible tempo.

Mechanistic warfare attempted to maintain order and ward off chaos through a preprogrammed and centralized routine devoid of any capacity for reactivity to the actions of the opposing army. With virtually all initiative removed from individual soldiers, success required that the commanding officers meticulously plan ahead the course of the battle and dictate in advance the series of manœuvres to be carried out. Although this model was the product of lengthy developments which can be traced back to the Dutch armies of Maurice of Nassau at the turn of the seventeenth century, Frederick the Great's Prussian army embodies best the principles and practices of mechanistic warfare.

Thermodynamic warfare and the engine

With thermodynamics and the engine, science gained an understanding of the energy that drove the previously studied mechanisms of motion. As the study of heat derived from the engineering prowess that produced the steam engine, nineteenth-century thermodynamics revolutionized the scientific world-view through the discovery of both the convertibility of all forms of energy (chemical, electrical, kinetic or other) and their inevitable dissipation into randomness through entropy (the inherent tendency towards the dissipation of useful energy). No longer appearing reversible but acquiring direction, time was said to have found its arrow, one leading to the inevitable heat death of the universe in an inevitable progression from order to chaos. With the formulation of entropy in particular came a probabilistic approach to scientific problems, undermining the tidy linearity and precise predictability of mechanistic models.

The thermodynamic world was one of instability and change in which the cultivated stability of the *ancien régime* was swept away by revolutionary and nationalistic fervour. But if time found its arrow, it was not always from order to chaos. Ideologies of progress also proclaimed a direction to history, at the end of which lay a liberal, socialist or national paradise. From the chaos of the age, a final and immutable order would emerge, even if more disorder would first be required in the form of war or revolution, those great 'engines' of history. Narratives of optimistic progress and fearful decline alternated in the cultural imagination of nineteenth- and early twentieth-century Europe. But if there were conflicting accounts of the direction time was taking, what remained undisputed was the new impermanence of the world and the uncertainty it brought with it. As the founder of 'scientific socialism' Karl Marx famously put it, 'all that is solid melts into the air' in the foundry of the new industrial world. The engine, the device that put to work the sources of motive power and was central to industrialization, replaced clockwork as the dominant mechanical model, and became the theoretical and practical nexus for the new scientific world-view.

Thermodynamic warfare saw the channelling into war of ever greater flows of energy, whether of a ballistic, motorized, industrial or moral nature, as nation-states clashed in ever wider conflicts that drew on all the resources at their disposal. Entire societies were mobilized as war became total. Beginning with the feverish *élan* of the French Revolution and Napoleonic wars of conquest, thermodynamic warfare culminated in the ultimate paroxysm of the Second World War and the detonation of the atom bomb. If the logistical requirements of industrial warfare brought whole economies under unprecedented centralized control, the chaos of the battlefield imposed some tactical decentralization, notably through the German army's *Auftragstaktik*, the mission-oriented tactics successfully experimented with by stormtrooper units during the First World War and subsequently developed into *Blitzkrieg*.

Thermodynamic thought also expressed itself in the writings of Clausewitz, who recognized the essentially dynamic and irreducibly unpredictable nature of war, and theorized the inevitable friction and fog inherent in military operations. Chaos was here understood as intrinsic to the practice of warfare, a constant threat to the best laid plans: something that military commanders should be able to recognize and adapt to, rather than engaging in self-defeating attempts to banish it.

Cybernetic warfare and the computer

As the intensity and breadth of the battlefield grew along with its logistical requirements, new communication technologies became necessary to achieve the required integration and coordination of increasingly large and intricate military systems. The harnessing of electromagnetic forces for telecommunication purposes proceeded with telegraphy and telephony, simultaneously stimulating growing scientific interest in the concept of information. Cybernetics emerged from the unprecedented technological and industrial effort of the Second World War, in particular the work on the automation of anti-aircraft defences. The self-proclaimed 'science of communications and control' promised to manage chaos and disruption through self-regulating mechanisms of negative information feedback. By being defined in terms of negative entropy (negentropy), information became conceptualized as the source of all order. The computer, also developed during the war for the purposes of code-breaking and the computation of nuclear physics, emerged as the new dominant technology and abstract model through which the world came to be understood chiefly in terms of information processing.

The drive for complete predictability and centralized control over armed conflict was renewed under cybernetic warfare with the deployment of computers and automated control technologies, and the widespread application of the analytical tools of operations research and systems analysis.[15] The Cold War and the constant threat of nuclear annihilation required ever greater levels of automation and centralization of the war machine; and cybernetics, with its promise of stability in the face of perturbation, appeared best suited to the containment and management of a conflict of potentially apocalyptic proportions. Vast command and control architectures were established to organize the global projection of armed force and the rapid mobilization of military systems within the shrinking windows of opportunity afforded by nuclear weaponry. Scientific methodology was applied to warfare more systematically than ever, with operations research and systems analysis applied comprehensively to both tactical and strategic questions. The first two decades of the postwar era saw the rise of the defence intellectuals and their analytical tools in the United States, culminating in the nomination of Robert McNamara as Secretary of Defense.

In its most pristine form, cybernetic warfare fuelled wild yet enduring fantasies of omniscience and omnipotence on the battlefield. In 1969 General William Westmoreland, commander-in-chief of US forces in Vietnam, formulated his vision of the military's future, encapsulating this cybernetic ideal:

[15] See Antoine Bousquet, 'Cyberneticizing the American war machine: science and computers in the Cold War', *Cold War History* 8: 1, Jan. 2008, pp. 771–1102.

On the battlefield of the future, enemy forces will be located, tracked, and targeted almost instantaneously through the use of data links, computer assisted intelligence evaluation, and automated fire control. With first round kill probabilities approaching certainty, and with surveillance devices that can continually track the enemy, the need for large forces to fix the opponent becomes less important. I see battlefields that are under 24-hour real or near-real time surveillance of all types. I see battlefields on which we can destroy anything we can locate through instant communications and almost instantaneous application of highly lethal firepower … In summary, I see an Army built into and around an integrated area control system that exploits the advanced technology of communications, sensors, fire direction, and the required automatic data processing … With cooperative effort, no more than 10 years should separate us from the automated battlefield.[16]

Although this vision of a fully automated and frictionless military machine has persisted to this day and inspired many subsequent advocates of a revolution in military affairs, recent scientific developments have challenged the theoretical frameworks underpinning cybernetic warfare, bringing with it a new regime of the scientific way of warfare.

Towards chaoplexic warfare

Since the mid-1970s, the cybernetic mode of warfare has come under increasing challenge from the military reversal for US forces in Vietnam, geopolitical transformation following the end of the Cold War, and novel scientific developments growing out of the original corpus of cybernetics. The increasing application of computers to the study of scientific problems, the exploration of non-linear mathematics, and an extension of the cybernetic analysis of systems to questions of self-organization opened the way for novel scientific approaches which eventually crystallized into the theories of chaos and complexity (here referred to together as *chaoplexity*). Information remains the central concept, and in this sense chaoplexity is an outgrowth of cybernetics; but the focus on change, evolution and positive feedback breaks with the cybernetic pioneers' concern for stability. Chaos is seen no longer as simply a threat to order which must be averted at all costs, but as the very condition of possibility of order. The key notions here are those of non-linearity, self-organization and emergence, and the pivotal technological figure is that of the network, the distributed model of information exchange perhaps best embodied by the internet.

The science of chaoplexity

Although still firmly set in the informational paradigm, chaos theory and complexity science departed from cybernetics in shifting the focus away from the stabilizing self-regulation (or homeostasis) underlying the persistence of existing systems towards runaway processes of change leading to the emergence of new

[16] William Westmoreland, address to the Association of the US Army, 14 Oct. 1969. See Paul Dickson, *The electronic battlefield* (Bloomington, IN: Indiana University Press, 1976), pp. 215–23.

systems or patterns of behaviour. Non-linear dynamics and positive feedback processes, whereby small causes can amplify into large effects, are crucial here. Chaos theorists have used computer simulations of non-linear systems to reveal how initially minute variations can ramp up into dramatic changes in the long-term behaviour of the system. The popular image invoked to illustrate this phenomenon is the 'butterfly effect': the notion that a butterfly flapping its wings in (say) Tokyo can cause a tornado in (say) California. While chaos theory has imposed serious limits on the ability to predict the long-term behaviour of systems, it has also provided new insights, uncovering a subtle order and structure to phenomena previously believed to be completely devoid of recognizable patterns, such as the turbulence of fluids or plate tectonics.

Building on the original insights of chaos theory, complexity scientists turned to the interactions of the different component parts of living systems, and particularly to the new properties and behaviours constituted through the networked self-organization of autonomous agents. Self-organization is the process by which the autonomous interaction of individual entities results in the bottom-up emergence of complex systems, systems composed of many parts which are connected in a non-linear fashion. The notion of the network is central to describing the patterns of interaction which are constituted by the interplay of entities in a complex system: 'The first and most obvious property of any network is its non-linearity—it goes in all directions. Thus the relationships in a network pattern are non-linear relationships. In particular, an influence, or message, may travel along a cyclical path, which may become a feedback loop. The concept of feedback is intimately connected with the network pattern.'[17]

Of special interest are the 'complex adaptive systems' which display the ability to change and learn from experience. Complexity theorist John Holland defines a complex adaptive system as a dynamic network of many agents acting simultaneously, constantly both acting and reacting to what the other agents are doing. Since the control of a complex adaptive system tends to be highly dispersed and decentralized, any coherent behaviour in the system arises from competition and cooperation among the agents themselves. It is the accumulation of all the individual decisions taken by the multitude of agents which produces the overall behaviour of the system, which can thus be said to be emergent.[18] Complex adaptive systems include living organisms, insect colonies, bird flocks, ecosystems, businesses, stock markets and other forms of social organization; the constituent agents may be cells, species, individuals, firms or nations.

From the perspective of chaoplexity, the most successful systems are those that retain flexibility and openness in the interaction and organization of their parts within environments which elude complete predictability. No longer is order to be sought in a natural tendency towards equilibrium. On the contrary, it is with non-equilibrium that order emerges from chaos, at the point where instability

[17] Fritjof Capra, *The web of life: a new synthesis of mind and matter* (London: Flamingo, 1997), p. 82.

[18] M. Mitchell Waldrop, *Complexity: the emerging science at the edge of order and chaos* (London: Viking, 1992), pp. 145–6.

and creative mutation allow for the genesis of new forms and actions.[19] As Ian King puts it, 'networking [is] a way of maintaining a low-level chaotic substrate so that—as in the brain—the chaos will from time to time give birth to an intellectual self-organizing structure'.[20]

Decentralized self-organizing systems are inherently better equipped than centralized systems to deal with limited predictability and contingency. According to the biologist Christopher Langton, 'since it's effectively impossible to cover every conceivable situation, top-down systems are forever running into combinations of events they don't know how to handle. They tend to be touchy and fragile, and they all too often grind to a halt in a dither of indecision.'[21] In contrast, decentralized systems of quasi-autonomous units can operate more effectively and with a greater degree of adaptability on the basis of the local calculations of the networked agents constituting them. For Stuart Kauffman, 'networks in the regime near the edge of chaos—this compromise between order and surprise—appear best able to coordinate complex activities and best able to evolve as well'.[22]

Chaoplexity has challenged some of the most deeply held scientific convictions about the natural world and opened up whole new areas of research. It is now also increasingly weighing on the debates about military organization, heralding a new era in the scientific way of warfare.

The dawn of chaoplexic warfare

Cybernetic warfare experienced its first serious reversal with the Vietnam War, where its analytical techniques and military systems foundered in the conditions of a low-intensity conflict. James Gibson has written persuasively about the failure in the jungles of South-East Asia of 'technowar', an approach to military conflict in which war was viewed as 'a production system that can be rationally managed and warfare as a kind of activity that can be scientifically determined by constructing computer models'.[23] The conduct of the war was blighted by the attempts of the military and political hierarchy to micro-manage the conflict and by an obsession with statistical evaluation and information-gathering which frequently created assessments of the war that were completely at variance with the reality on the ground. Despite the deployment of an unprecedented telecommunications network in the field of operations, command and control technologies failed to perform as expected, with saturation and bottlenecks preventing information on Vietcong positions and movements from arriving in time to be actionable. Perhaps most seriously, a misguided faith in the powers of technoscience to grant military omnipotence led policy-makers to embrace armed force more willingly as the means to solve complex strategic problems. Such hubris was perfectly

[19] Ilya Prigogine and Isabelle Stengers, *Order out of chaos: man's new dialogue with nature* (London: Fontana, 1985), p. 287.
[20] King, *Social science and complexity*, p.55.
[21] Waldrop, *Complexity*, p. 279.
[22] Stuart A. Kauffman, *At home in the universe: the search for laws of self-organization and complexity* (London and New York: Oxford University Press, 1995), p. 26.
[23] James Gibson, *The perfect war: technowar in Vietnam* (Boston: Atlantic Monthly Press, 1986), p. 156.

encapsulated by Henry Kissinger's claim in 1968 that 'a scientific revolution has, for all practical purposes, removed technical limits from the exercise of power in foreign policy'.[24]

The debacle in Vietnam provoked some soul-searching among strategists and military men but did not result in an immediate abandonment of the central principles of cybernetic warfare, which continued to dominate military thinking through the 1980s. All the early contributions to the debate on the revolution in military affairs were premised on the idea that computers, telecommunication links and precision-guided munitions would finally deliver the frictionless, automated battlefield promised by Westmoreland. However, new thinking drawing on the emerging non-linear sciences did begin to penetrate military theory, at first espoused only by isolated individuals but entering the mainstream at the turn of the century.

The late US air force colonel John Boyd is perhaps the most prominent pioneer of chaoplexic warfare, and increasingly is considered to be one of the most important military thinkers of recent times.[25] Boyd is best known for his formulation of the OODA loop (observe–orient–decide–act), describing the decision-making process of the warfighter engaged in combat. Although this is at first sight reminiscent of a typical cybernetic feedback loop, whereby a system adjusts its behaviour to incoming information from its environment in order to meet a desired objective, Boyd was insistent on the need for the analytical frameworks used during the orientation phase to be continually challenged and reinvented through a perpetual process of 'destruction and creation'.[26] No predetermined automated response can prevail for long in a world that is 'uncertain, everchanging, unpredictable'.[27] Boyd went on to contribute to US Marine Corps doctrine, which displays clear signs of the influence of chaoplexity in asserting that 'the best we can hope for is to impose a general framework of order on the disorder, to prescribe the general flow of action rather than to try to control each event',[28] and that 'like a living organism, a military organization is never in a state of stable equilibrium but is instead in a continuous state of flux—continuously adjusting to its surroundings'.[29]

If the earlier proclamations of an imminent revolution in military affairs remained firmly tributary to cybernetic conceptions, the ascent of network-

[24] Henry Kissinger, 'Central issues of American foreign policy', in Henry Kissinger, *Agenda for a nation* (Washington DC: Brookings, 1968).

[25] Having presented his ideas mainly through briefings in his lifetime, Boyd has left very little written exposition of his theories (the 1976 paper 'Destruction and creation' being the main exception. Available at http://www.chetrichards.com/modern_business_strategy/boyd/destruction/destruction_and_creation.htm, accessed 10 August 2008). Osinga's in-depth examination of Boyd's ideas and of his personal library provides one of the most thorough discussions of his thought and sets out in detail the extent to which it was influenced by scientific developments: Frans Osinga, *Science, strategy and war: the strategic theory of John Boyd* (Abingdon, UK: Routledge, 2007).

[26] Boyd, 'Destruction and creation'.

[27] Boyd, 'The conceptual spiral' (presentation, 1992). Available at http://www.d-n-i.net/boyd/pdf/intro.pdf, accessed 10 Aug. 2008.

[28] *FMFM1: warfighting*, United States Marine Corps (Washington DC: Department of the Navy, 1989), pp. 9–10. Available at http://www.marines.cc/downloads/FMFM1/FMFM1-1.pdf, accessed 10 Aug. 2008.

[29] *MCDP 6: command and control*, United States Marine Corps (Washington DC: Department of the Navy, 1996), p. 46. Available at http://www.dtic.mil/doctrine/jel/service_pubs/mcdpb.pdf, accessed 10 Aug. 2008.

centric warfare (NCW) marked the onset of a shift towards chaoplexic notions on the centre ground of debates over military doctrine. With its ideas couched in the language and concepts of the non-linear sciences, NCW first appeared on the scene within the US navy in the late 1990s before rapidly rising to become the new official Pentagon gospel under the agenda of 'Transformation' with the founding of the Office of Force Transformation in 2001 under the stewardship of its original formulator Vice Admiral Arthur Cebrowski. According to Cebrowski, network-centric warfare views war as a 'complex, adaptive system where non-linear variables continuously interact'.[30] Since 'coordination from the top down inevitably results in delays and errors in force dispositions', the military should seek to acquire 'the ability of a well-informed force to organize and coordinate complex warfare activities from the bottom up'.[31] For Cebrowski, what is being proposed is nothing less than a 'new theory of war'.[32]

Such a new theory can emerge only by breaking with the command and control principles that governed cybernetic warfare during the Cold War, as suggested by Alberts and Hayes:

> Control Theory requires both prediction and the existence of an adequate set of levers of control … [But] having effective, centrally managed levers that can control or even predictably influence a complex, adaptive system is far from guaranteed … In the Information Age, control needs to be thought about and approached differently. Control is not something that can be imposed on a complex adaptive system, particularly when there are many independent actors. Control, that is, ensuring that behavior stays within or moving to within acceptable bounds, can only be achieved indirectly. The most promising approach involves establishing, to the extent possible, a set of initial conditions that will *result* in the desired behavior. In other words, control is not achieved by imposing a parallel process, but rather emerges from influencing the behaviors of independent agents.[33]

NCW theorists claim that through the distribution of information across the battlefield and the constitution of a common operational picture via an overarching 'Global Information Grid', command and control will be decentralized and individual troops will be freed to act on their own initiative, leading to self-synchronization, a clear nod to the chaoplexic notion of self-organization. New tactical schemes denied to their hierarchical counterparts are seen as the emergent properties that will be unlocked by fully networked self-synchronizing forces. Drawing further from the writings of complexity theorists and deploying biological metaphors, military theorists appeal to the 'swarm', the networks of distributed intelligence that enable bees, ants and termites to evolve complex forms of collective behaviour on the basis of the simple rules of interaction of their individual members. Of particular interest are the resilience and flexibility of

30 Gray, *Strategy for chaos*, p. 105.
31 Arthur K. Cebrowski, 'Sea, space, cyberspace: borderless domains', speech delivered to US Naval College, Newport, RI, 26 Feb. 1999.
32 'When you rack and stack all of that what we are really talking about is a new theory of war because we are talking about new sources of power': Arthur Cebrowski, speech delivered to Network-Centric Warfare conference, Arlington, VA, 22 Jan. 2003.
33 David S. Alberts and Richard E. Hayes, *Power to the edge—command … control … in the information age* (Washington DC: Department of Defense CCRP, 2003), pp. 206–8.

these swarms as amorphous ensembles whose continued existence and successful operation is not critically dependent on any single individual. Military swarms promise not only more adaptable and survivable forces but also new offensive and defensive tactics better suited to the contemporary battlespace.

According to Alberts and Hayes, decentralization and information-sharing will permit military platforms to 'evolve from being networked entities to being nodes in the network, to organizing efforts resembling "packs" and "swarms"'. The ensembles of different entities making up fighting forces, whether human or robotic, will 'ultimately become dynamically reconfigurable packs, swarms, or other organizations of highly specialized components that work together like the cells of our bodies' and will be 'less mechanical and more organic, less engineered and more "grown"'.[34]

Beyond the flexibility and evolutionary capability that are attributed to military swarms, it is also claimed that they will be able to bring force to bear in a new manner. Rather than throwing themselves onto the enemy in 'waves', forces will be able to converge on their target from all directions in offensive bursts, thereby maximizing the shock effect. For Arquilla and Ronfeldt, the full effects of swarming are achieved when

> the dispersed nodes of a network of small (and also perhaps some large) forces can converge on an enemy from multiple directions, through either fire or maneuver. The overall aim should be *sustainable pulsing*—swarm networks must be able to coalesce rapidly and stealthily on a target, then dissever and redisperse, immediately ready to recombine for a new pulse. A swarm network should have little to no mass as a rule (except perhaps during a pulse), but it should have a high energy potential—like a swarm of bees that can fell a mighty beast, or a network of antibodies that can attack a spreading virus.[35]

Troops that can disperse swiftly after an attack or 'pulse' also have the advantage of being less vulnerable to enemy attacks, particularly in the context of the high lethality and precision characteristic of contemporary and future battlefields.

The promises of network-centric warfare are bold and, for all its deployment of chaoplexic language, the doctrine suffers from a number of potentially critical weaknesses. In several respects it has not significantly broken with cybernetic warfare and therefore may not in fact implement all the features of a truly chaoplexic way of warfare.

While 'decentralization' is the order-word of the day, the networking of troops may in fact provide the technological infrastructure for greater micro-management than ever by a military brass which will have access to data feeds from anywhere in the battlespace. Second, dependence on a unified 'Global Information Grid' could both create a critical vulnerability likely to be targeted by competent adversaries and deprive troops of the skills required to respond creatively to situations in which only limited local information is available (as most of the complex adaptive

[34] Alberts and Hayes, *Power to the edge*, p. 169.

[35] John Arquilla and David Ronfeldt, 'Looking ahead: preparing for information-age conflict', in John Arquilla and David Ronfeldt, eds, *In Athena's camp: preparing for conflict in the information age* (Santa Monica, CA: RAND, 1997), p. 465.

systems studied are found to do). Furthermore, NCW advocates fall back all too often on impoverished conceptions of Boyd's OODA loop which substitute speed of execution of predetermined responses for creative thinking and adaptability to the unforeseen. Finally, there persists a tendency to see information technology as the panacea which will permanently lift the friction and fog of war which has plagued all past militaries, when in fact chaoplexity points to the irreducible contingency and unpredictability of war and the need to organize so as to tolerate and even take advantage of this uncertainty.[36]

Ultimately chaoplexic warfare will depend more on doctrinal and organizational commitments than on any particular information technologies, which are liable to be employed to quite contrary purposes. The full arrival of chaoplexic warfare may therefore still lie ahead; but the debates around network-centric warfare clearly show an impetus towards greater decentralization and the use of the network form of organization within armed forces. NCW now has its counterparts in most major western militaries, including Network Enabled Capabilities (NEC) in the United Kingdom, NATO Network Enabled Capabilities (NNEC), and Network Enabled Operations (NEOps) in Canada. Where such militaries have encountered recent setbacks, for example in Iraq, Afghanistan or Lebanon, it has been against opponents that have employed decentralized networks to good effect against better-equipped forces, thereby further stimulating discussion about their merits and underlining the limitations of established modes of operation. Just as the ideas of mechanism, thermodynamics and cybernetics inspired past military thought and practice in association with their respective paradigmatic technologies, a new set of scientific theories are now occupying a central role within the doctrinal and organizational changes of the armies of the early twenty-first century. Our network age is therefore also that of chaoplexity.

[36] For a detailed critique of network-centric warfare and its relation to previous scientific approaches to war, see Antoine Bousquet, *The scientific way of warfare: order and chaos on the battlefields of modernity* (London: Hurst; New York: Columbia University Press, forthcoming 2009).