Network-Centric Warfare: Its Origin and Future

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Arising from fundamental changes in American society and business, military operations increasingly will capitalize on the advances and advantages of information technology.

Here at the end of a millennium we are driven to a new era in warfare. Society has changed. The underlying economics and technologies have changed. American business has changed. We should be surprised and shocked if America's military did not.

For nearly 200 years, the tools and tactics of how we fight have evolved with military technologies. Now, fundamental changes are affecting the very character of war. Who can make war is changing as a result of weapons proliferation and the fact that the tools of war increasingly are marketplace commodities. By extension, these affect the where, the when, and the how of war.

We are in the midst of a revolution in military affairs (RMA) unlike any seen since the Napoleonic Age, when France transformed warfare with the concept of levŽe en masse.[1] Chief of Naval Operations Admiral Jay Johnson has called it "a fundamental shift from what we call platform-centric warfare to something we call network-centric warfare,"[2] and it will prove to be the most important RMA in the past 200 years.

Network-centric warfare and all of its associated revolutions in military affairs grow out of and draw their power from the fundamental changes in American society. These changes have been dominated by the co-evolution of economics, information technology, and business processes and organizations, and they are linked by three themes:

- The shift in focus from the platform to the network
- The shift from viewing actors as independent to viewing them as part of a continuously adapting ecosystem
- The importance of making strategic choices to adapt or even survive in such changing ecosystems[3]

These themes have changed the nature of American business today, and they also have changed and will continue to change the way we conduct the sometimes violent business of the military. We are some distance from a detailed understanding of the new operations--there is as yet no equivalent to Carl von Clausewitz's On War for this second revolution--but we can gain some insight through the general observation that nations make war the same way they make wealth.

The Underlying Economics Have Changed

The organizing principle of network-centric warfare has its antecedent in the dynamics of growth and competition that have emerged in the modern economy. The new dynamics of competition are based on increasing returns on investment, competition within and between ecosystems, and competition based on time. Information technology (IT) is central to each of these.

The U.S. economy has been on a steady growth path generally attributed to the emergence of larger global markets, the globalization of labor and capital, and the widespread application of information technology within business enterprises.[4] To get an idea of the magnitude of investment in information technology, consider the fact that the information technology sector--only a small fraction of the economy (3% in 1996)--has been the largest contributor to growth in gross domestic product. In 1996, its contribution was 33%, with an average of 27% over the past three years.[5] Within this sector, competition based on increasing returns has emerged as a new dynamic.

The preponderance of competition in the economy is characterized by decreasing returns on investment. Referred to here as "Economy A," it is characterized by stability, market share equilibrium, and decreasing returns on investment. Competing products or services are interchangeable, and multiple companies provide roughly comparable goods and services. As a result, there is no mechanism for product lock-in. Efforts to increase market share yield decreasing returns on investment because of constraints in intellectual capital, physical plant, or distribution or because of the response of a competitor.

Competition based on increasing returns is different. "Economy B" is the much smaller but much discussed part of the economy characterized by extraordinary growth and wealth generation, increasing returns on investment, the absence of market share equilibrium, and the emergence of mechanisms for product lock-in.[6] It is the engine for America's powerhouse economy. Competing products are based on competing standards, are not necessarily interoperable, or require skill sets that are not easily transferable. This is especially true of key types of information technology, such as video cassette recorders, personal computers, and communications technology. In addition, in key sectors of Economy B, the laws of supply and demand that govern Economy A have been turned on their heads. As demand for personal computers increases, for example, price for constant performance decreases.

In Economy B, a product or product standard attains such a dominant position that consumers drop competing products because of concerns about the availability of "content" or product support or because they prefer a familiar product based on existing skills or content. In the case of the typewriter, lock-in was based on the skill set associated with the "QWERTY" keyboard. For the VCR, lock-in was based on the VHS price/performance advantage over Beta and was reinforced by the content providers' decision to release movies in VHS format. Everyone who bought Beta switched and lock-in was achieved.

With personal computers, lock-in of the Windows-Intel (WINTEL) standard emerged as a result of multiple factors that combined to reduce the intially dominant Apple Computer

technology to a niche. An important early advantage was a new business computing application (the spreadsheet) optimized to run on the DOS-Intel standard introduced by IBM. In the first three months after the introduction of Lotus 1-2-3, IBM's PC sales tripled. This initial success was reinforced by a superior licensing strategy, the emergence of PC clones, and the decision by software vendors to develop applications first for the ecosystem with the largest market share--WINTEL.[7] Locking-out competition and locking-in success can occur quickly, even overnight. We seek an analogous effect in warfare.

The Underlying Technologies Have Changed

Information technology is undergoing a fundamental shift from platform-centric computing to network-centric computing. Platform-centric computing emerged with the widespread proliferation of personal computers in business and in the home. The significant investment the IT sector makes in research and development and product development (in some cases up to 18% of sales) has led to key technologies that have created the conditions for the emergence of network-centric computing.

This shift is most obvious in the explosive growth of the internet, intranets, and extranets.[8] Internet users no doubt will recognize transmission control protocol/internet protocol (TCP/IP), hypertext transfer protocol (HTTP), hypertext markup language (HTML), Web browsers (such as Netscape Navigator, and Microsoft's Internet Explorer), search engines, and JavaTM Computing.[9] These technologies, combined with high-volume, high-speed data access (enabled by the low-cost laser) and technologies for high-speed data networking (hubs and routers) have led to the emergence of network-centric computing. Information "content" now can be created, distributed, and easily exploited across the extremely heterogeneous global computing environment.

Network-centric computing is governed by Metcalfe's Law, which asserts that the "power" of a network is proportional to the square of the number of nodes in the network.[10] The "power" or "payoff" of network-centric computing comes from information-intensive interactions between very large numbers of heterogeneous computational nodes in the network. Sun Microsystems may have been the first to point out that it is not so much about the computer as it is about the computer in the networked condition. Under fierce competitive pressure, and sensing a strategic opportunity in this fundamental shift in computing, IBM Chairman Lou Gerstner announced that IBM was moving to network-centric computing.[11] The compelling business logic for this shift in strategy was the opportunity for IBM to link its heterogeneous computing lines more effectively and provide increased value for its customers. This is the same value proposition we seek in warfare.

The Business of America Has Changed

The emergence of the dynamic and unstable Economy B has changed the American way of business significantly. First, many firms have shifted their focus to the much larger, adaptive, learning ecosystems in which they operate. Not all actors in an ecosystem are

enemies (competitors); some can have symbiotic relationships with each other. For such closely coupled relationships, the sharing of information can lead to superior results. Second, time has increased in importance. Agile firms use superior awareness to gain a competitive advantage and compress timelines linking suppliers and customers. Even firms that operate in Economy A have found ways to harness Economy B technologies and techniques to increase efficiency and productivity. Central to these developments is the shift to network-centric operations, which are characterized by information-intensive interactions between computational nodes on the network. Whether these interactions are focused on commerce, education, or military operations, there is "value" that is derived from the content, quality, and timeliness of information moving between nodes on the network.[12] This value increases as information moves toward 100% relevant content, 100% accuracy, and zero time delay--toward information superiority.

Dominant competitors across a broad range of areas have made the shift to network-centric operations--and have translated information superiority into significant competitive advantage[13]--but the benefits are particularly apparent in transaction-intensive operations, such as retailing and securities trading. Wal-Mart and Deutsche Morgan Grenfell are two firms that have made the shift to network-centric operations. (See "Information Superiority" sidebar). Both have gained tremendous competitive advantages by co-evolving their organizations and processes to exploit information technology. Characteristic of big winners, they employ network-centric operational architectures that consist of a high-powered information backplane (or information grid), a sensor grid, and a transaction grid. These architectures provide the ability to generate and sustain very high levels of competitive space awareness, which is translated into competitive advantage.

Leading U.S. firms have come to understand and employ this network calculus well.

- The shift from platform to network is what enables the more flexible and more dynamic (and profitable) network-centric operation. Therefore, the construction of high-quality networks is their top priority.
- The shift from viewing partners as independent to viewing partners as part of a continuously adapting ecosystem increases speed and profitability in both sales and production. Therefore, they have developed high-speed sensor grids and automated command-and-control systems closely coupled with their transaction grids.
- The key to market dominance lies in making strategic choices appropriate to changing ecosystems. Simply pursuing operational effectiveness while adhering to an obsolete strategy is a formula for failure.

How Can the Military Not Change?

Network-centric operations deliver to the U.S. military the same powerful dynamics as they produced in American business. At the strategic level, the critical element for both is a detailed understanding of the appropriate competitive space--all elements of battlespace and battle time. Operationally, the close linkage among actors in business ecosystems is

mirrored in the military by the linkages and interactions among units and the operating environment. Tactically, speed is critical. At the structural level, network-centric warfare requires an operational architecture with three critical elements: sensor grids and transaction (or engagement) grids hosted by a high-quality information backplane. They are supported by value-adding command-and-control processes, many of which must be automated to get required speed.

Network-centric warfare enables a shift from attrition-style warfare to a much faster and more effective warfighting style characterized by the new concepts of speed of command and self-synchronization. Attrition is the traditional "Economy A" analogue because it yields decreasing returns on investment. Reversals are possible, and frequently the outcome is in doubt.

Network-centric warfare, where battle time plays a critical role, is analogous to the new economic model, with potentially increasing returns on investment. Very high and accelerating rates of change have a profound impact on the outcome, "locking-out" alternative enemy strategies and "locking-in" success. There are two complementary ways that this is accomplished:

- Network-centric warfare allows our forces to develop speed of command.
- Network-centric warfare enables forces to organize from the bottom up--or to self-synchronize--to meet the commander's intent.

Speed of command has three parts: (1) The force achieves information superiority, having a dramatically better awareness or understanding of the battlespace rather than simply more raw data. Technologically, this will require excellent sensors, fast and powerful networks, display technology, and sophisticated modeling and simulation capabilities. (2) Forces acting with speed, precision, and reach achieve the massing of effects versus the massing of forces. (3) The results that follow are the rapid foreclosure of enemy courses of action and the shock of closely coupled events. This disrupts the enemy's strategy and, it is hoped, stops something before it starts. One of the strengths of network-centric warfare is its potential, within limits, to offset a disadvantage in numbers, technology, or position.

Speed of command facilitates the lock-out phenomenon observed in Economy B, but with even more powerful effects. Lock-out often takes years to achieve in business, but in warfare it can be achieved in weeks or less.

The joint suppression of air defense mission provides an example at the tactical level of how the increased combat power associated with network-centric operations can contribute to speed of command and lock-out. The High-speed Anti-Radiation Missile (HARM) is used to suppress or destroy enemy surface-to-air missile (SAM) sites. When we employ platform-centric operations in this scenario, we achieve virtually no kills. The HARM still will suppress the SAM sites--because site operators realize that these missiles are out there and so adjust their behavior--but those sites will stay there through the duration of the war. Consequently, aircraft that carry HARM missiles have to fly

throughout the entire campaign, and all strike aircraft continue to be at risk. By shifting to modern digital technology, we can increase battlespace awareness to yield increased combat power, with more targets destroyed. But if, through co-evolution of systems, organization, and doctrine, we introduce other shooters that are capable of attacking SAM sites, such as ATACMS, and employ them as part of an engagement grid, virtually all of the sites can be destroyed in the same amount of time. It is easy to focus on the number of sites destroyed, but the payoff is in the initial very high rate of change. When 50% of something important to the enemy is destroyed at the outset, so is his strategy. That stops wars--which is what network-centric warfare is all about.

Military operations are enormously complex, and complexity theory tells us that such enterprises organize best from the bottom-up. Traditionally, however, military commanders work to obtain top-down command-directed synchronization to achieve the required level of mass and fires at the point of contact with the enemy. Because each element of the force has a unique operating rhythm, and because errors in force movement needlessly consume combat power, combat at the operational level is reduced to a step function, which takes time and provides opportunity to the enemy. After the initial engagement, there is an operational pause, and the cycle repeats.

In contrast, bottom-up organization yields self-synchronization, where the step function becomes a smooth curve, and combat moves to a high-speed continuum. The "Observe-Orient-Decide-Act (OODA) Loop" appears to disappear, and the enemy is denied the operational pause. Regaining this time and combat power amplifies the effects of speed of command, accelerating the rate of change and leading to lock-out. Self-synchronization was illustrated during the Taiwan Straits crisis. In 1995, when the People's Republic of China attempted to influence Taiwanese elections with some high-quality saber rattling, the United States quickly dispatched carrier battle groups, and the situation seemed to settle out. For our purposes, the most exciting part of that story was the fundamentally different way that command and control was exercised. Then-Vice Admiral Clemins, as Commander, Seventh Fleet, and his subordinates reduced their planning timelines from days to hours. This order of magnitude change suggests that something very fundamental is happening.

One reason we say that no plan survives initial contact with the enemy is because situational awareness does not. In platform-centric military operations, situational awareness steadily deteriorates. It is reestablished periodically, but it only then deteriorates again. Network-centric operations such as those used in the Taiwan Straits example create a higher awareness, and allow it to be maintained. Such awareness will improve our ability to deter conflict, or to prevail if conflict becomes unavoidable. This is not just a matter of introducing new technology; this is a matter of the co-evolution of that technology with operational concepts, doctrine, and organization. The enabler, of course, is technology. In the Taiwan case, Admiral Clemins was able to use e-mail, a very graphic-rich environment, and video teleconferencing to achieve the effect he wanted.

We are beginning to see the broad impact of network-centric warfare throughout the fleet, as key technology building blocks are deployed. In early 1997, a single aircraft carrier in the western Pacific sent 54,000 e-mails in one month--about half the amount of all of the traditional message traffic that was sent in Western Pacific during the same time. That is an example of a very complex outfit organizing itself from the bottom up. Now it is the norm. Such capabilities enable a move into the realm of speed of command. Questions decrease because ambiguity decreases, collegiality increases, and timelines shorten.

The Emerging Logical Model

The structural or logical model for network-centric warfare has emerged. The entry fee is a high-performance information grid that provides a backplane for computing and communications. The information grid enables the operational architectures of sensor grids and engagement grids. Sensor grids rapidly generate high levels of battlespace awareness and synchronize awareness with military operations. Engagement grids exploit this awareness and translate it into increased combat power.[14] Many key elements of these grids are in place or available. For example, at the planning level, the elements of a DoD-wide intranet are emerging. To assure interoperability, all elements of the grids must be compliant with the Joint Technical Architecture and the Defense Information Infrastructure common operating environment. However, their full integration into a more powerful warfighting ecosystem is only partially complete.

This is not theory--it is happening now. For example, new classes of threats have required increased defensive combat power for joint forces. The combat power that has emerged--the cooperative engagement capability (CEC)--was enabled by a shift to network-centric operations.[15] CEC combines a high-performance sensor grid with a high-performance engagement grid. The sensor grid rapidly generates engagement quality awareness, and the engagement grid translates this awareness into increased combat power. This power is manifested by high probability engagements against threats capable of defeating a platform-centric defense. The CEC sensor grid fuses data from multiple sensors to develop a composite track with engagement quality, creating a level of battlespace awareness that surpasses whatever can be created with stand-alone sensors. The whole clearly is greater than the sum of the parts.

How to Get There

No one operates better than the U.S. Navy. Our forward presence force is the finest such force in the world. But operational effectiveness in the wrong competitive space may not lead to mission success. More fundamentally, has the underlying rule set changed so that we are now in a different competitive space? How will we revalue the attributes in our organization?

To choose a sporting example, although the objective of the game, the number of plays, and the operating environment are essentially the same, football is fundamentally different from soccer because its underlying rule set is different. Accordingly, the competitive attributes of mass, continuity of play, self-synchronization, sustained speed,

and others are revalued. There are important differences between the ways a soccer coach and a football coach would recruit, train, and organize their teams.[16]

Similarly, if we decide to fight on a network-centric rather than platform-centric basis, we must change how we train, how we organize, and how we allocate our resources. A good understanding of our competitive space, therefore, is vital to achieving success. The Navy, indeed all services, must make these strategic decisions to maximize future combat power and relevance. Because a network-centric force operates under a different, more modern rule set than a platform-centric force, we must make fundamental choices in at least three areas: intellectual capital, financial capital, and process.

- Intellectual Capital. Information-based processes are the dominant value-adding processes in both the commercial world and the military. Yet the military fails to reward competence in these areas. "Operator" status frequently is denied to personnel with these critical talents, but the value of traditional operators with limited acumen in these processes is falling, and ultimately they will be marginalized, especially at mid-grade and senior levels. The war fighter who does not understand the true source of his combat power in such things as CEC, Global Command and Control System, and Link-16 simply is worth less than those who do. The services must both mainstream and merge those with technical skills and those with operational experience in these areas. These are the new operators.

  Every new revolution in military affairs produces a new elite. The inherent cultural changes are the most difficult and protracted. We must start now. While we delay, our people, our most vital asset, are deciding that they want to compete on a different team.

- Financial Capital. Navy decision making across a broad front is aligning with the network-centric warfare strategy. We are moving forward rapidly with ship- and aircraft-launched weapons that have reach, precision, and responsiveness, and advanced C2 concepts are under development.

  The Navy's umbrella strategy for enabling the IT elements of network-centric warfare is Information Technology for the 21st Century (IT-21). It provides for accelerated implemetation of customer-led command, control, communications, computers, and intelligence (C4I) innovations and existing C2 systems/capabilities (programs of record). The Navy's commitment to funding IT began in fiscal year 1997. For the fiscal year 1999 budget request and the Future Years Defense Program, Navy funding for IT-21-related programs exceeds $2.5 billion. Battle groups and amphibious ready groups are deploying with increasing network capabilities.

  All elements of the network-centric warfare model must move forward if the promise of the revolution is to be realized. Delays will mean higher costs, reduced combat power, and, in the joint arena, failure to achieve the concepts of Joint Vision 2010.

- Transformation Process. In spite of a ponderous acquisition process, technology insertion is ahead of and disconnected from joint and service doctrine and organizational development. The problem is cultural and systemic. A process for the co-evolution of technology, organization, and doctrine is required.

  Service experimentation programs are a vital first step. While the temptation may be to take some units out of readiness reporting status for use in an experimental force, the result would be to isolate the larger force from the process. The objective is to create an ethos for experimentation, innovation, and a willingness to risk across the entire force. Specific top-down experimentation will be required because of cost and size or to establish overarching priorities, but these are expected to spawn experiments from the bottom up and facilitate cultural and organizational changes. That is the concept behind the Navy's Fleet Battle Experiment Program.

The concepts of network-centric operations, shifting competitive spaces, changing underlying rule sets, and co-evolution are not mere theory. They have been applied successfully under demanding conditions with encouraging results. Similarly, these concepts are not limited to a few optimum circumstances. The crime rate in New York City, for example, was reduced dramatically through the application of these concepts. (See "Co-Evolution" sidebar.)

We may be special people in the armed forces, but we are not a special case. It would be false pride that would keep us from learning from others. The future is bright and compelling, but we must still choose the path to it. Change is inevitable. We can choose to lead it, or be victims of it. As B. H. Liddell Hart said, "The only thing harder than getting a new idea into the military mind is getting an old one out."

Note: *Network-Centric Warfare* derives its power from the strong networking of a well-informed but geographically dispersed force. The enabling elements are a high-performance information grid, access to all appropriate information sources, weapons reach and maneuver with precision and speed of response, value-adding command-and-control (C2) processes--to include high-speed automated assignment of resources to need--and integrated sensor grids closely coupled in time to shooters and C2 processes. Network-centric warfare is applicable to all levels of warfare and contributes to the coalescence of strategy, operations, and tactics. It is transparent to mission, force size and composition, and geography.

Speed of Command is the process by which a superior information position is turned into a competitive advantage. It is characterized by the decisive altering of initial conditions, the development of high rates of change, and locking in success while locking out alternative enemy strategies. It recognizes all elements of the operating situation as parts of a complex adaptive ecosystem and achieves profound effect through the impact of closely coupled events.

Self-Synchronization is the ability of a well-informed force to organize and synchronize complex warfare activities from the bottom up. The organizing principles are unity of effort, clearly articulated commander's intent, and carefully crafted rules of engagement. Self-synchronization is enabled by a high level of knowledge of one's own forces, enemy forces, and all appropriate elements of the operating environment. It overcomes the loss of combat power inherent in top-down command directed synchronization characteristic of more conventional doctrine and converts combat from a step function to a high-speed continuum.

1. The levee en masse was a shift from the previous model of maintaining a small professional army. France was able to take advantage of the changes in society from industrialization to take nearly the entire adult male population to war, transforming the nature of armed conflict during the Napoleonic era.
2. Address at the U.S. Naval Institute Annapolis Seminar and 123d Annual Meeting, Annapolis, MD, 23 April 1997.
3. James F. Moore, "The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems," HarperBusiness, 1996.
4. Stephen B. Sheperd, "The New Economy: What It Really Means," Business Week 17 November 1997, pp. 38-40.
5. Michael J. Mandel, et al., "The New Business Cycle," Business Week, 31 March 1997, pp. 58-68.
6. W. Brian Arthur, "Increasing Returns and the New World of Business," Harvard Business Review, July-August 1996, pp. 100-109; Self-Reinforcing Mechanisms in Economics: the Economy as an Evolving Complex System (Addison-Wesley, 1988), pp. 9-31.
7. Robert X. Cringely, "Accidental Empires," HarperBusiness, 1992, pp. 139-158.
8. Amy Cortese, "Here Comes the Intranet," Business Week, 12 February 1996, pp. 76-84.
9. Bud Tribble, et al., "JavaTM Computing in the Enterprise: What It Means for the General Manager and CIO," Sun Microsystems, Inc., white paper.
10. George Gilder, "Metcalfe's Law and Legacy," Forbes ASAP, 13 September 1993.
11. Ira Sager, "The View from IBM," Business Week, 30 November 1995.
12. "Technology and the Electronic Company," IEEE Spectrum, February 1997.
13. Philip L. Zweig, et al., "'Beyond Bean Counting," Business Week, 18 October 1996.
14. See "The Emerging Joint Strategy for Information Superiority," Joint Staff J-6, information briefing at www.dtic.mil/JCS/J6.
15. "The Cooperative Engagement Capability," Johns Hopkins APL Technical Digest 16, 4 (1995): 377-96.
16. The example was developed by Col. Fred P. Stein, USA (Ret.).

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