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Network-centric Warfare

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NETWORK-CENTRIC WARFARE

What's the Point?

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What *is* network-centric warfare? What's the point? Many attempts to answer these questions emphasize the "network" and the new technologies used to create more effective sensor and communications architectures. These architectures, it is argued, will enable us to create and exploit a common situational awareness, increase our speed of command, and "get inside the enemy's OODA [observe, orient, decide, and act] loop."[1] Yet such descriptions of technologies and capabilities can leave us asking the same questions: What is it? Just what does it bring to warfare? Why is it so critical to America's future military power that we must give up other capabilities to buy it?

These questions highlight the need for a warfare-centered working concept of network-centric operations. Such conceptual work can help us both recognize the potential in networking and discern its limits and limitations. It also can provide a fundamental understanding of the role of network-centric operations on the battlefield and across the spectrum from peace through war. An evolving working concept is, in short, the first step in designing a network-centric "navy after next."

Using technology to multiply the impact of military forces seems almost axiomatic. The problem is in identifying which technological combinations hold the most potential. Information technology is one obvious force multiplier, but what we really face are three concurrent technological revolutions.[2]

The first is in *sensor technology*. The sensor revolution is twofold: one movement toward sensors able to achieve near-real-time surveillance over vast areas, and another toward smaller, cheaper, more numerous sensors that

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can be netted to detect, locate, identify, and track targets. Together, these trends can produce systems that will provide the quantity and quality of data needed to create a "situational awareness" that is "global in scope and precise in detail."[3] The second revolution is in *information technology*. The information revolution will bring the geometric increase in computing power necessary to process, collate, and analyze this vast quantity of sensor data, and it will provide means to distribute information to any recipient or "shooter" anywhere in the world at near-real-time speeds. The third is in *weapons technology*. The weapons revolution is a matter of increasing numbers of precise munitions by reducing costs. It, like the sensor revolution, is twofold. Better streams of targeting data can permit a "dumbing down" of expensive guidance packages, while new designs, electronics, "lean" manufacturing, and mass production can decrease the cost for a given level of accuracy and capability.[4]

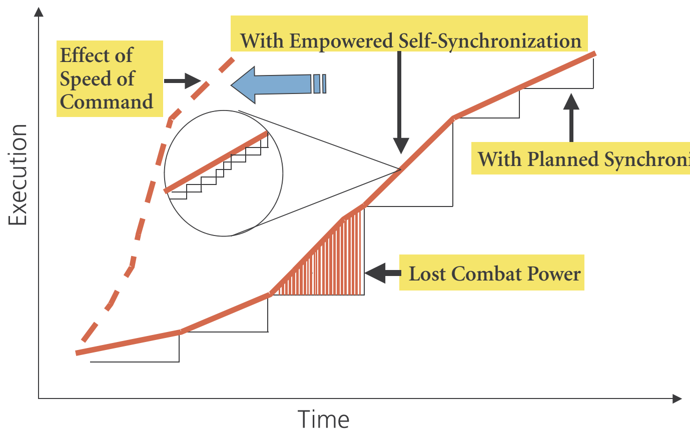
In the coming decade, these revolutions will interact and multiply each other's impacts and create a kaleidoscope of potential synergies that will change the character of war as we know it.[5] These revolutions and this change in how we think about war have come to be embodied in the idea of network-centric operations.

NETWORK-CENTRIC OPERATIONS

The first step in creating a working concept for network-centric operations is identifying the key changes that grow from the triple technological revolution. One change, clearly, is the increased precision and speed that may now be possible in military operations. Speed and precision make it feasible to exploit specific battlefield opportunities and operate at a pace calculated to overwhelm an enemy's capacity to respond. They also offer a highly agile force, able to change from one rapid, precise operation to another at will and able to compress complex targeting processes to fit the nearly real-time dimensions of the battlefield. These emerging possibilities signal changes in how we wage war.

The leading network-centric proponents explain the impact of network-centric warfare in this manner. In traditional military operations, a mission is assigned and planned, forces are generated, and operations are executed to concentrate power on an objective. This is a highly coordinated, "stepped" cycle: periods of relative inaction, during which forces are generated and actions coordinated (the flat part of the step) alternate with periods of action, when combat power is applied (the vertical part). However, if forces were networked to create near-real-time situational awareness (see figure 1), we could act continuously. We would no longer need to pause before deciding on further action; the information and coordination needed would already be there. Moreover, shared awareness would permit a flattened, decentralized command structure, with decisions made at the lowest practical level of command—a

FIGURE 1
SELF-SYNCHRONIZATION AND SPEED OF COMMAND



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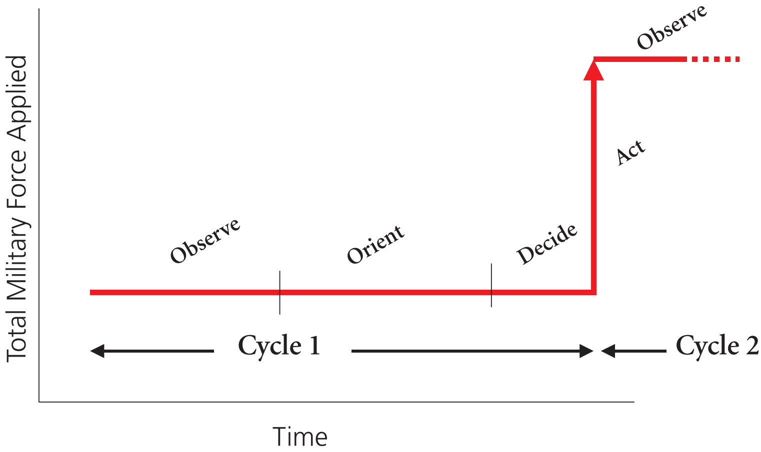
"self-synchronization" that would permit us to reclaim "lost combat power." Then, as we train and organize to optimize these capabilities, the pace of these semi-independent operations would accelerate further to permit a new "speed of command." This description makes clear that network- centric operations are really about optimizing combat power—that is, *combat efficiency*.

While equating accelerated, self-synchronized operations to increased combat efficiency makes intuitive sense, it needs further explanation. One approach is to look at the above-mentioned "steps" in the context of the well known work of Colonel John Boyd, U.S. Air Force, but treating OODA loops as a succession of linear cycles overlaid on the steps.[6] Boyd's "observe," "orient," and "decide" phases then would equate to the flat part of a step, while the "act" phase would be the vertical. Plotted on axes of time (x) versus cumulative application of military force (y), the steps become OODA cycles, with each "act" adding to the total of the military force applied (see figure 2).

This construct of a *combat cycle* brings us to look not just at decision making but also at the parallel process of generating combat power. For example, the "observe" process includes both the decision to observe certain activities and the physical actions needed to acquire the intelligence, surveillance, and targeting data and then transmit it to the right people or systems. New sensor and information technologies can compress this process significantly, but there is a limit to how much. To optimize the impact of precision, we need more than sensor-based awareness; we need to identify specific vulnerabilities, and to do that we need to know the enemy. Such knowledge draws on sensor information—and will be subject to some time compression as a result—but it also depends on regional expertise and on intelligence databases developed long before the battle begins. Thus, the new sensors and information technology can shorten the cycle only to the degree that long-term collection and analysis are already available on the net.

FIGURE 2
OODA CYCLE



A similar limit emerges in the combined "orient and decide" phase.[7] Better awareness helps us avoid mistakes and use assets more efficiently, but we must still complete a set of physical actions to generate military power. We may have to move an aircraft carrier into range of the objective, plan and brief a mission, fuel and arm aircraft, and launch them. We may also have to deliver follow-on air strikes to achieve an objective. The pace of these actions is determined by the physical capabilities of systems and people; a carrier can move only so fast, and flight deck operations can be hurried along only so much. "Efficiency" here is as much a function of how we organize, train, and equip our forces as it is of information flows. The same is true of the "act" phase. Once in the air, aircraft must proceed toward the target and then—at a time dependent on the speed and range of the weapons used and the distance they must travel—launch their ordnance.

To increase combat efficiency, therefore, we must accelerate both parts of the combat cycle, the OODA cycle and the process of generating combat power. A strike-sortie-generation demonstration conducted by USS *Nimitz* (CVN 68) in 1997 is a good example of how these two elements come together.[8] *Nimitz* used only a rudimentary network to aid targeting and decision making, but it then focused on optimizing the operations of the carrier and the air wing to make better use of the increased information that the network made available. For this demonstration, among other things, *Nimitz* added pilots to its air wing, introduced new high-speed cyclical operations, and relied on accompanying missile ships for air defense.[9] The result was a fourfold increase in sorties over a four-day period. Arming each aircraft with multiple precision weapons, each of which could reliably destroy an aim point, further multiplied the effect. The battle group thus established a faster, more efficient power-generation cycle, one that produced—when combined with networks' ability to identify the "targets that count" in commensurate numbers—an order-of-magnitude increase in the group's combat efficiency.

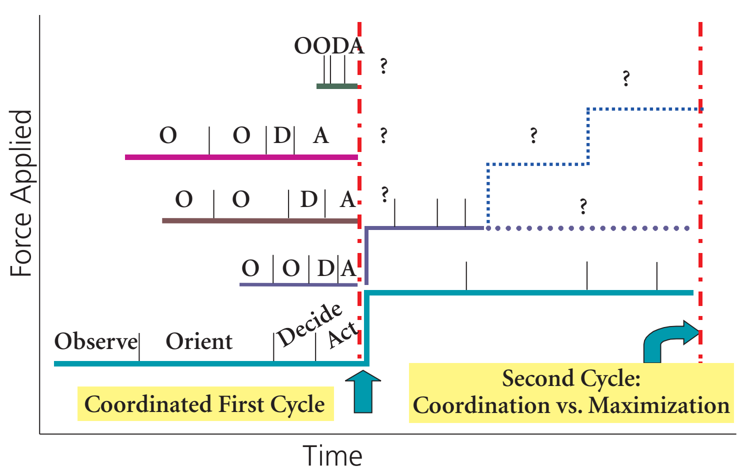
This is significant for several reasons. First, the *Nimitz* operation shows that using better equipment, organization, training, and information can shorten power-generation cycles and thus take advantage of network-centric speed and awareness. However, it also indicates that the time required for power generation varies with equipment, training, and organization; that in turn suggests that dissimilar military forces have power-generation cycles of radically different lengths. For example, the length of *Nimitz*'s cycle would differ from that of a squad of SEALs (Navy special operations forces) inserted from a submarine, a cruiser firing Tomahawk land-attack missiles, a squad of Marines in a firefight, or bombers operating from bases in the continental United States.

In a traditional battle, the commander manages the complex interaction among different combat cycles by so coordinating units that their respective "act" phases strike the enemy at the same time or in some prescribed sequence. The more diverse the forces, the greater the coordination problem.[10] The entire effort is held hostage to the speed of the slowest combat cycle, all other units being deliberately kept from achieving their optimum operational tempos so as to mass effects or be mutually supportive. This forgoes additional cycles that might have been applied by quicker-paced forces, and as a result, less power is applied overall (see figure 3). In short, by optimizing mass, we minimize efficiency.

Here is where agility becomes important. Precision and speed permit us to reduce cycle length and thereby increase the pace of operations, but they are insufficient by themselves to create a warfare revolution—or prevent it from backfiring. To deal with changes in the enemy threat or take advantage of emerging battlefield opportunities, we must be able *both* to conduct rapid, semi-independent operations *and* to mass forces and effects as required. We must be able to change the mode, direction, and objectives of our actions, just as much as we need to bring speed and precision to targeting.

This agility and the speed and precision it exploits all derive from the amalgam of information, sensors, and communications that constitutes the "information backplane" of network-centric operations. The network permits us to

FIGURE 3
COORDINATED ATTACK . . . THEN WHAT?



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undertake more actions in a given time, to focus those actions better, and to act and react faster and with more certainty. Yet, these attributes—better, faster, more—still add up to little more than a more efficient form of attrition. How do we make the leap to a level of efficiency that would permit us to break enemies' wills rather than simply grind down their means of waging war?

EFFECTS-BASED OPERATIONS

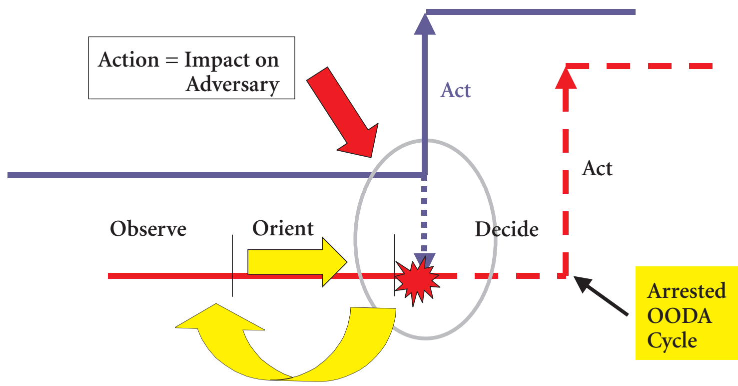
While increasing the number of aim points struck, the volume of fire generated, or the damage inflicted remains a critical, irreducible core of what military forces do, it is only the first step toward combat efficiency. The real payoff in network-centric operations is foreshortening combat by causing the enemy to yield long before his means to resist have been exhausted, or long before additional friendly forces might be expected to arrive in the crisis area. This efficiency revolves around the ability of network-centric forces to undertake precise *effects-based operations*, that is, outcome-oriented activity focused on enemy behavior. The objective of these operations is psychological rather than physical. Hence, they are focused on the enemy's decision-making process and ability to take action in some coherent manner—especially "getting inside his OODA loop" and inducing or exploiting chaos. The knowledge, precision, speed, and agility brought by network-centric operations constitute the price of admission into this realm.

"Getting Inside OODA Loops"

In our OODA-cycle diagram, any "act" or application of combat power can be seen in two ways. From the perspective of straightforward attrition, it is an effort that attacks, destroys, or in some way degrades the enemy capability to wage war or sustain it. Yet, that same "act" is also a stimulus that enemies "observe" and factor into their decision-making processes. The more significant the action, the greater effect it will have on decisions. This "effect" is a function not solely of how much we destroy but of what and how we attack. If the stimulus is significant enough, the effect may be to force enemies to reconsider their courses of action and, perhaps, begin their decision-making cycles all over again. That is to say, we would disrupt their OODA loops. A succession of such stimuli might not only disrupt a foe's OODA loop but even create a condition of "lockout," in which the enemy can no longer react coherently (see figure 4).

The requirements for such effects-based operations are stringent. If we were concerned only with attrition, improvement in efficiency would require only increases in the size and frequency of our attacks—that is, the total quantity of power applied. Breaking the will, in contrast, requires putting the right forces on the right vulnerabilities at the right times so as to produce some particular effect.

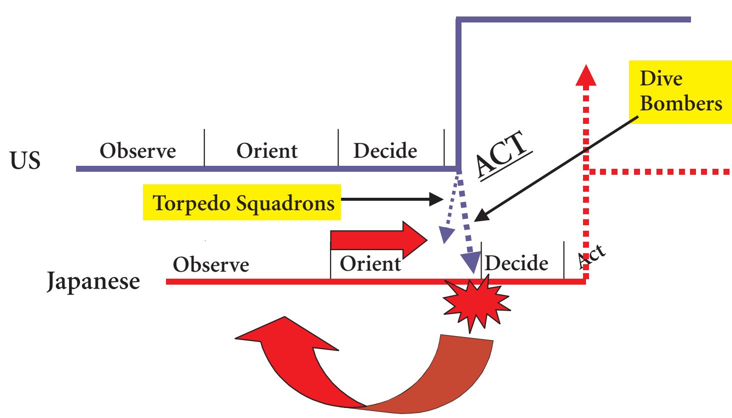
FIGURE 4
INTERACTION BETWEEN OODA CYCLES



To make matters more difficult, this needs to be done not just to a single enemy OODA cycle, as in a one-on-one fighter engagement, but against the multiple and interacting OODA cycles of different enemy units and forces, which are operating simultaneously at the tactical, operational, and strategic levels of conflict.

A pointed, if serendipitous, example of such a disruption occurred in the battle of Midway in June 1942. Intelligence derived from the breaking of Japanese codes enabled the Americans to anticipate the Japanese attack, detect enemy carriers before their own were found, and launch an attack first. When the Japanese commander received word of an American carrier in the area—just before he was attacked by carrier-based torpedo planes—he reconsidered a planned attack on Midway, reoriented his effort, and ordered his aircraft rearmed for fleet action. Then, as his planes were being rearmed and his combat air patrol aircraft were engaged in low-level intercepts of American torpedo planes, the dive-bomber element of the disjointed American attack (in figure 5, the second dotted arrow) struck, catching the Japanese carriers with their decks full of planes and bombs.[11] What happened in the next minutes ended the Japanese attack on Midway and was the turning point in the Pacific War. In effect, the sighting of one ship and a tactically ineffective torpedo-plane attack had collectively, and fortuitously, a

FIGURE 5
MIDWAY



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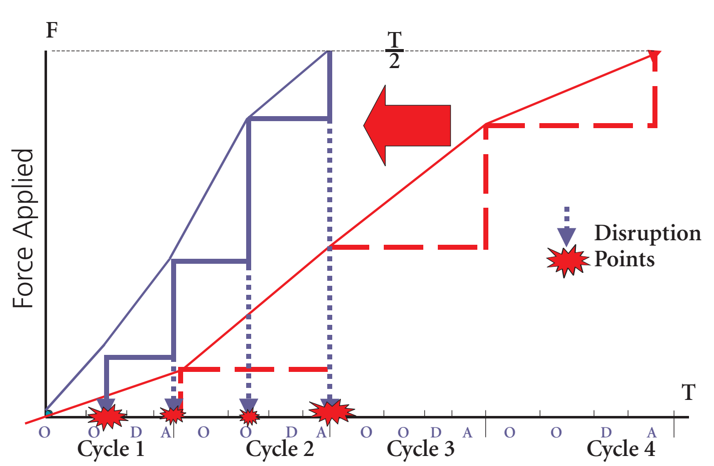
decisive impact on the enemy OODA cycle: they occurred at just the right time and forced the Japanese to begin anew. The challenge for network-centric operations is to repeat this effect reliably, predictably, and at will. How do we do that?

If we compare the Japanese and American combat cycles at the time of the torpedo attack, it becomes evident that the cycles were out of phase with each other. Had they been in phase, American and Japanese strikes would have passed each other in the air and struck empty decks on both sides, without the disastrous consequences for the Japanese—but possibly dire ones for the smaller force of American carriers. But thanks to its intelligence coup, the American side completed its observation, orientation, and decision phases in time for its air-strike "act" to hit the Japanese when they were most vulnerable and before they could initiate a fleet action. The American success rested partly on careful preparation—the intelligence, reconnaissance, and early launch of aircraft—and in part on the serendipity of the poorly (in terms of the plan) coordinated arrival of their strike elements over the target.

To emulate Midway, we must measure the enemy OODA cycle correctly and then coordinate our actions to occur at exactly the right times. This requires not only the "battlespace awareness" that in 1942 enabled the American fleet to launch its strikes first but also knowledge of the enemy necessary to identify and exploit critical junctures.[12] We must then be able to sustain controlled, high-tempo operations. There is a problem here: intelligence simply will not yield such knowledge of the enemy reliably, consistently, or at all levels.[13] How then might network-centric operations enable us to bring about another Midway?

One solution is to multiply the number of opportunities to repeat the Midway serendipity. The more frequent the stimulus, the greater the chance a strike will occur at the right time to obtain the desired effect on the enemy decision-making process. Shortening the length of our overall combat cycle (see figure 6) would multiply the number of impacts on an adversary's decision making over a given period and increase the likelihood of striking at the "right time" to disrupt the

FIGURE 6
COMPRESSION OF TIME

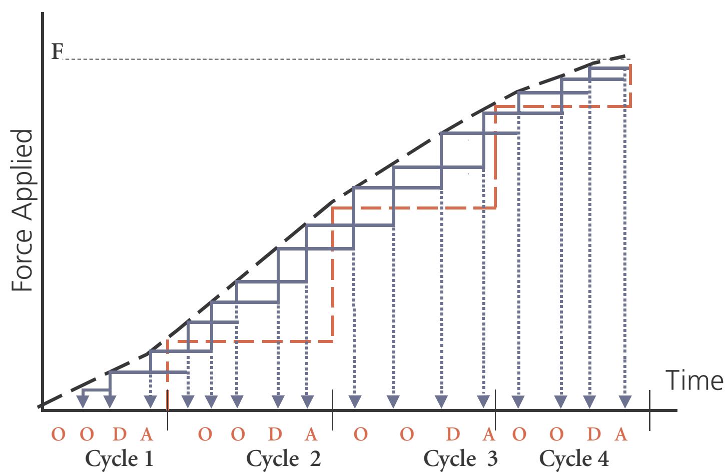


adversary's cycle. But as we have noted, the power-generation side of the combat cycle can be compressed only so much.

Another approach would be to build on "self-synchronization" and "shared situational awareness" to launch smaller, more numerous operations, each of which could generate a stimulus sufficient to affect the adversary's OODA cycles.[14] The length of the individual unit combat cycles might remain the same, but they could be staggered, overlapped, so as to produce a rapid succession of stimuli. This approach has an obvious limitation: the more we diminish the size of our individual actions, the more vulnerable each will be to defeat in detail. However, with better awareness and better knowledge of the enemy, we can hope to anticipate enemy actions and optimize forces for disruptive effect or for mutual support (see figure 7).

Finally, we could multiply the number of cycles but also compress the time needed to execute each cycle. In essence, we would use our network-centric capability to liberate individual forces to operate at their respective optimum combat cycles and by so doing increase the number of OODA cycles we execute. Ideally, the stimuli can be made numerous enough to overwhelm enemies with new developments, forcing them continually to revisit decisions, redirect efforts, and pause for observations, even to the point that they cannot ever take action.

FIGURE 7
MULTIPLE OVERLAPPING CYCLES



This suggests an analogy very different from that of Midway. Instead of thrusting a rapier into the OODA cycle at precisely the critical time, we could unleash something akin to a swarm of bees. Even if no single unit has a decisive impact, the overall effect might be to leave the victim swinging helplessly at attackers coming from all directions, unable to mount any coherent defense save retreat. In essence, we would provide so many stimuli that adversaries could no longer act coherently but must constantly recycle: "Does the act that just struck me invalidate the assumptions upon which my currently intended course of action rests? Does it demand a redirection of my effort? Will an

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additional attack come, and will it force me into revisiting my plans yet again?" The result would be lockout.

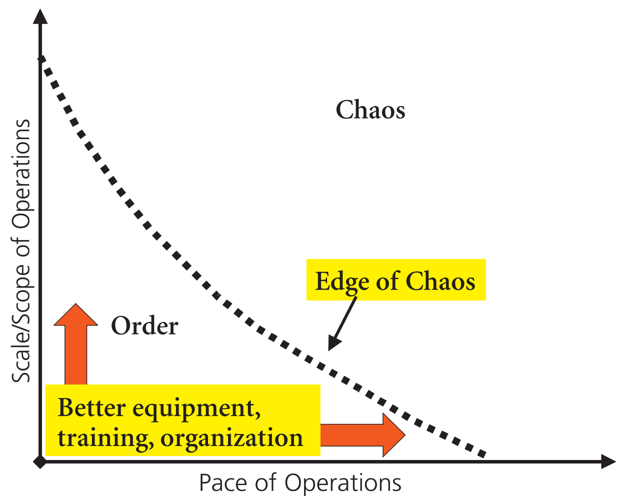
This "swarm" approach poses new challenges. How do we coordinate the swarm so as to achieve concrete military objectives beyond simply interfering—perhaps without success—in the enemy decision-making loop? How do we know when to mass forces or effects so as to avoid their being destroyed one by one? How do we assess the effectiveness of our efforts and then feed the results of these assessments into the next round of "orient," "decide," and "act" phases? Will enemies *know* they have been defeated and cease to resist, or simply continue to swat at the attacks until they can no longer do so—that is, continue a blind attrition war? To be effective, the "swarm" would need to work toward a unified set of military objectives, under a single commander's intent, whereas to achieve sufficiently brief cycle times, its individual elements must be largely self-contained and self-coordinated. In short, our forces would need to become self-synchronized and self-adaptive—but those are key capacities we hope to draw from network-centric operations.

Exploiting Chaos

The principle of chaos in warfare is not new.[15] Clausewitz talks in terms of exploiting the fog and friction of war to drive the enemy into a rout—that is, into a state of chaos.[16] Recent writings on "chaos theory" have drawn a comparison between the concept of chaos in physical systems and its application to warfare.[17] The boundary region between chaos and order is particularly significant, because small inputs or changes in system parameters there can have very large impacts, even causing entire systems to collapse. In military operations, this would equate to creating situations in which relatively small applications of power at the right time have highly disproportionate and potentially decisive impacts. This is particularly significant for expeditionary warfare and forward presence, in that it suggests that a relatively small forward force might exploit chaos to offset what it lacks in numbers.

How do we define this boundary region in militarily useful ways? A simple approach is to define the edge of chaos in terms of the intensity of the operations, specifically the pace and the scale and scope of operations, which can be plotted along the x and y axes of a coordinate scale. We can understand intuitively that the more we increase the pace of our operations (x), the more difficult they will be to manage. Similarly, the greater the scope and scale of our operations (y), the more difficult they will be to control. By extension, we can surmise that at some point along the x axis lies an operation so rapid that we cannot coordinate it, and that somewhere on the y axis is an operation (such as a global thermonuclear war) of such size or scope that we lose control of our forces; beyond either of these points

FIGURE 8
DEFINING THE EDGE OF CHAOS



we lapse into chaos ourselves (see figure 8). These two points represent transitions from order into chaos. Figuratively, then, a line drawn between these two points is the *edge of chaos*—it defines the limit of our control, and it contains all order-to-chaos transition points.

In this context, *chaos* encompasses all military operations that are so rapid or of such scale as to be uncontrollable and that are, therefore, unfocused and incoherent, such as a rout on a battlefield—"every man for himself."[18] The opposite is *order*—military operations whose scale, scope, and pace permit them to be controlled, coordinated, and focused on given objectives. Historically, when armies and navies have met in battle, at least one tactical objective has been to drive the enemy force from order into chaos. How can we identify and exploit this operational boundary?

One factor is that the edge of chaos is not fixed. It changes constantly. As the *Nimitz* demonstration underlined, a highly trained and organized force using sophisticated equipment can operate safely at a pace and scale of operations that would push a less well-trained and equipped force into chaos. Better equipment, training, and organization, then, enable us to drive our transition points farther out along the x and y axes and thereby define new edges of chaos. This also means that the edge of chaos varies from one force to the next, as each comprises different units, differently equipped, manned, trained, and organized. Opposing forces in any battle are therefore likely to have their own, quite different, edges of chaos. These two edges of chaos define three zones. Zone 1 (see figure 9) is the zone of chaos—all the combinations of scale, scope, and pace that neither side would be able to manage. Zone 2 defines a complex, asymmetric region in which the better equipped and trained force can coordinate operations but the other cannot. In Zone 3 is the realm in which both sides can operate comfortably—the zone of order.

By definition, neither side can operate successfully in Zone 1, and neither derives any advantage from operating in a way that permits its enemy an orderly and focused response (Zone 3).[19] In contrast, the boundary region, Zone 2, offers

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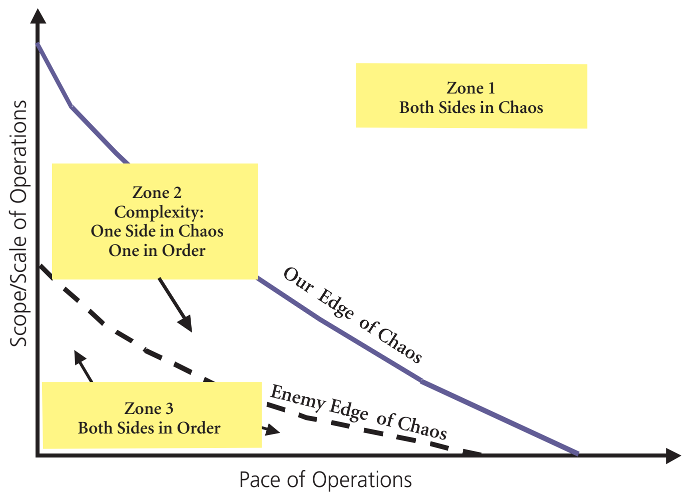
FIGURE 9
OPERATIONS ON THE EDGE OF CHAOS



the disproportionate impacts predicted by chaos theory. It is a regime of inherent asymmetry, in which the less capable side can neither respond in kind nor fail to respond (and be pummeled into submission or confined to preplanned actions, unresponsive to the situation).[20] This can be carried another step. If one side is consistently able to operate beyond the other's edge of chaos, it can induce a state of despair in which further resistance is, or at least appears to be, futile. Focusing precisely on vulnerabilities most likely to drive the enemy into chaos can accelerate this process.

SELF-SYNCHRONIZATION AND ASYMMETRIC WARFARE

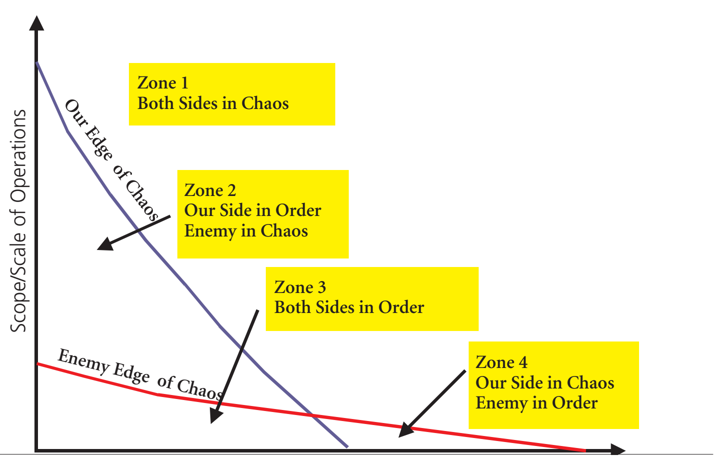
This all leads us to self-synchronized operations, of which a good historical example is the 1805 battle of Trafalgar, in which Admiral Horatio Nelson destroyed the combined French and Spanish fleets. The crux of the action was Nelson's bold movement to break through the French-Spanish battle line in two places and then concentrate his forces on bite-sized portions of it. The basis for success in so risky an undertaking was what could be described as a "cerebral network" among Nelson and his ship captains, his "band of brothers." That network had been formed by more than eight years of combat operations together; Nelson was confident that all of his subordinates would perceive a developing situation in the same way—that is, that they would have a shared situational awareness.[21] He was equally sure that his commanders not only understood his intent but would exploit aggressively any opening in the enemy line accordingly and carry out mutually supportive actions without further direction. For that reason, Nelson could limit his final directive before the battle to the inspiring, but otherwise not very helpful, reminder that "England expects every man to do his duty." Nothing more was needed. The commanders knew what to do.

This contrasted sharply with the situation of the opposing commander, Admiral Villeneuve. His force was larger and in many ways technologically superior, but it lacked any semblance of the cerebral networking Nelson had forged. The French ship captains and subordinate commanders had spent most of the war blockaded in port. They distrusted Villeneuve, even as Villeneuve distrusted his own judgment. Added to this was the problem of coordinating with a Spanish fleet, with which the French had never before operated. The best Villeneuve could do was to form his ships into a conventional eighteenth-century line of battle, foreseeing an engagement in which two ordered, parallel battle lines would pound each other until most of the ships of one side or the other struck their colors, blew up, or sank. When Nelson refused battle on these terms and instead broke through the French-Spanish line, the pace of operation that he thereby forced on the French and Spanish immediately exceeded their ability to cope and invalidated their numerical superiority. Villeneuve largely lost control of his forces and with it the ability to fight a coherent battle. In such conditions his ships, though they fought bravely, could only contribute to the general chaos; a substantial proportion never entered the battle at all.

Network-centric operations can, after a fashion, replicate the cerebral networking of Nelson's band of brothers without the eight years of combat preparation and without the slow tempo of battle at sea that facilitated situational awareness in the early nineteenth century. However, there is a hitch: What would happen if one side's edge of chaos did not lie entirely on one side of the other's but crossed it (figure 10), producing a *second* asymmetric zone, in which the advantages were reversed?

This reversal points to a dangerously misleading assumption underlying much thinking today about the "revolution of military affairs": that the United States will always be technologically superior and thus fight faster and better. In reality, tempo of operations is not solely a function of technology; it is also a function of the centralization of command. One can choose to trade centralized control for speed and scope of operations. This may forgo some of the ability to mass effects on a specific objective, but if the effect sought derives from the pace and scope of the attacks rather than from the amount of destruction, or from a cumulative impact rather than specific actions, then this trade-off may be acceptable. In other words, one could confront a technologically superior enemy by creating a new asymmetric zone in which small, decentralized units could operate successfully but in

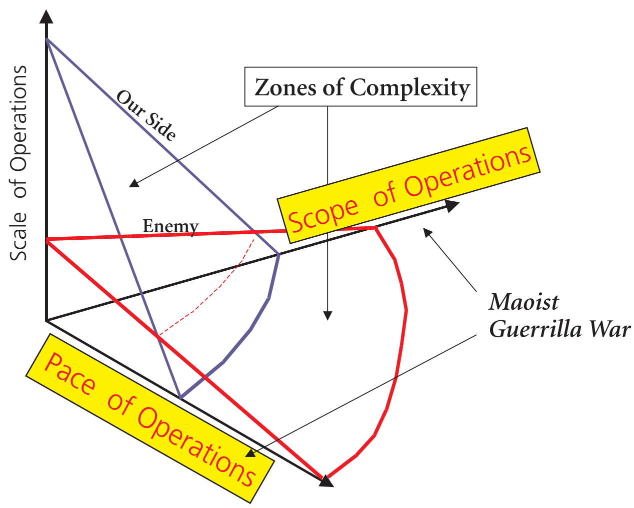
FIGURE 10
INTERSECTING EDGES OF CHAOS



which an opponent using large formations under centralized control could not respond coherently.

The importance of this fourth zone is even more evident if we plot the respective edges of chaos on a graph with three axes (figure 11)—one for pace, one for scale, and a separate orthogonal axis for scope. This presentation highlights two aspects of decentralization: forces can be broken into smaller, self-synchronized units, and they can be dispersed over a wide area to make coordinated and timely response by the other side more difficult. These points correspond rather closely to Maoist theory of guerrilla warfare. Guerrillas use dispersed formations so small that they cannot be targeted effectively by heavier government forces. These bands then conduct many small raids, so rapidly that the raiders are gone before opposing forces can be brought to bear. Since the desired effect, attrition of an opponent's will, depends more on pace and scope than on damage to specific targets, control can remain highly decentralized. This was the essential problem the United States confronted in Vietnam.

FIGURE 11
EDGE OF CHAOS—THREE AXES



These examples imply a new understanding of chaos—that chaos need not mean solely loss of control over one's forces. It could also mean a situation in which the size of forces and delays in generating and using them consistently prevent one side from accomplishing its objectives. How do network-centric operations address this low-tech asymmetry? One way is based on the knowledge and situational awareness brought to bear by the network. If the guerrillas' actions can be anticipated or instantly detected and responded to, much of what they gain by dispersing and decentralizing can be negated. In effect, networking permits the high-tech side to move its edge of chaos out from the *x* and *z* axes of the diagram until decentralization no longer confers any advantage on the guerrillas. Also, whereas by decentralization guerrillas or urban fighters opt for increasing the number and decreasing the size of their operations, a network-centric force might do the same—for example, by resorting to a ground war of small units aided by superior situational awareness. Alternatively, it could increase its pace, using the network to manage high-speed, complex operations. In each case, networking combined with self-synchronization enables forces to operate as a "self-adjusting complex adaptive system" while retaining the ability to mass superior effects at will.

A REALITY CHECK

As we gradually build a working concept of network-centric operations, we need to bear in mind some commonsense caveats. Networking is not a universal solution to warfare problems, nor will it change the nature of war. Older forms of warfare are likely to persist alongside the new. Speed will be critical to our success, but numbers and endurance will still count. Situational awareness will multiply our power, but knowing the enemy will be more important than ever. Above all, intelligent adversaries will respond, and the more successful our concept of network-centric operations becomes, the more asymmetrical their responses are likely to be.

But it is not our objective in developing a working concept to provide all the answers. It is simply to identify combinations of new thinking and new things that offer *better* answers to our warfare needs, on as many levels of war as possible, and over as wide a portion of the spectrum of conflict as possible. The measure of our success will be not the quality of the networking or the quantity of firepower we can bring to bear but the effect that networking enables us to have on our would-be enemies in peace and in war.

NOTES

1. Observe, Orient, Decide, Act—a cycle used by Colonel John R. Boyd, U.S. Air Force, to characterize fighter engagements and since then applied to the decision-making process in general. See John R. Boyd, *A Discourse on Winning and Losing* (Maxwell AFB, Ala.: Air Univ. Press, August 1987).
2. Walter Morrow, "Technology for a Naval Revolution in Military Affairs," Second Navy RMA Round Table, Science Applications International Corporation, Tysons Corner, Virginia, 4 June 1997.
3. Ibid.
4. This trend is already evident in the falling unit-price of the Navy Tomahawk cruise missile, from $1.2 million ten years ago to less than $700,000 in 1998, to possibly $300,000 or less before the decade is out—a roughly 50 percent drop every ten years. Daniel Murphy [Rear Adm., USN], "Surface Warfare," Navy RMA Round Table.
5. The situation is analogous to the triple revolution in guns, armor, and propulsion that marked warship design between 1862 and 1910—that is, from the commissioning of the USS *Monitor* to the first launch of an aircraft from a U.S. Navy ship. That threefold advance induced a period of trial and error that produced in turn such rapid change in warship design that new units were obsolete within a few years of entering service. It also brought forth Alfred Thayer Mahan and a fundamental rethinking of what navies could do.
6. Boyd.

7. In Boyd's tactical engagement loop, "orient" and "decide" are separated into two phases; however, this distinction becomes problematic in more complex operations, especially at the operational and strategic levels of war. As used here, the "orient" and "decide" phases are considered together, as collectively defining the time necessary to generate the right force to achieve the right effects.
8. The results of the *Nimitz* demonstration are detailed in a two-volume CNA study: Angelyn Jewell et al., *USS* Nimitz *and Carrier Airwing Surge Demonstration* (Alexandria, Va.: Center for Naval Analyses, 1998).
9. In the *Nimitz* case, the air wing was composed of low-maintenance, quick-turnaround F/A-18s, which could readily fly five or more sorties per day. The carrier air wing started with intense "flex-deck" operations but soon discovered that the flight deck became unworkable; the "edge of chaos" had been reached. It therefore switched to an aggressive concept of cyclical operations that enabled the wing to launch more aircraft while maintaining better order on the flight deck. Interview with Rear Adm. John Nathman, USN, Commander, *Nimitz* Battle Group, Pentagon, 11 February 1999.
10. The problem is especially bad in coalition operations, governed as they are by multiple national rules of engagement.
11. For the Japanese decision process and force-generation cycle at Midway, see Dallas W. Isom, "The Battle of Midway: Why the Japanese Lost," *Naval War College Review*, Summer 2000, pp. 60–100, esp. pp. 72ff.
12. In the Midway example, because the U.S. and Japanese forces were very alike, their OODA cycles would have been roughly similar. In a conflict between two dissimilar forces, that would not be the case, making the adversary's OODA cycle much more difficult to predict.
13. However good the surveillance picture or "battlespace awareness" we generate, the ultimate determinant of the speed and direction of the enemy decision-making cycle is the enemy. Sufficiently fine-grained knowledge of the enemy arises not from sensor data but from analysis based in large part on human-intelligence reporting—which is necessarily sporadic. We cannot, therefore, depend on having the intelligence when we need it or, indeed, on collecting the needed data at all.
14. Note that in each case the total amount of force applied remains constant and that what varies is the way in which that force is applied.
15. The idea of inducing chaos will hardly be a new concept to ground forces, for whom the fundamental challenge is to control very large numbers of "actors" in battle. In the ground context, "breaking the enemy's will to resist" equates to causing the enemy to disintegrate into panicked flight. While this understanding remains operative, the focus of the chaos sought here lies at the operational, even the strategic, level rather than the battlefield.
16. Barry Watts, *Clausewitzian Friction and Future War* (Washington, D.C.: National Defense Univ. Press, 1996), pp. 105ff.
17. Major Glenn James, U.S. Air Force, uses the example of a water faucet that drips with annoying regularity. As the flow of water is increased, the frequency of the drip rises but the regularity remains. However, when the flow is quickened even minutely beyond some definable rate, the drops no longer have time to form, and the drip changes abruptly to a sporadic—that is, chaotic—flow. The very minor increase in flow has caused the physical system to become chaotic. Glenn James, *Chaos Theory: The Essentials for Military Applications*, Newport Paper 10 (Newport, R.I.: Naval War College, 1997), pp. 15–6.
18. It is worth making a distinction here between tactical-level chaos that induces the enemy to take flight and strategic-level chaos that induces irrational behavior by a power with nuclear weapons. Between these two extremes lies a realm in which "shock and awe" can achieve specific effects calculated to support political and military objectives. However, implicit in the idea of effects is a risk-versus-gain calculus that applies to chaos as much as to other effects.
19. In the strategic nuclear confrontation of the Cold War, it was necessary to operate in this zone of order to avoid the risk of an irrational act or an uncontrolled escalation.
20. An example arose in the October 1973 Arab-Israeli War. The Egyptian army's "edge

of chaos" was far inside that of the Israelis. Therefore, the Egyptians were forced to resort to a scripted preemptive campaign. That gave them an initial success in crossing the Suez Canal but left them largely incapable of responding to Israeli counteraction.

21. The two fleets took more than three hours to close. This allowed ample time for the commanders to observe the enemy line and any gaps in it that they might exploit. The cerebral networking provided a common understanding of how such gaps might be exploited and of how ships might provide mutual support and exploit any further opportunities.