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Set and Drift

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SET AND DRIFT

BUILDING A BEEHIVE OBSERVATIONS ON THE TRANSITION TO NETWORK-CENTRIC OPERATIONS

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Conceptual changes always provoke institutional resistance. Some see network-centric operations (NCOs) as a high-speed train that will ultimately determine the size and shape of future naval forces. Others think NCO could derail important programs that they believe in. There are also concerns that monumental resource allocations could be pinned to such a new and undeveloped concept. This debate occurs at a time when there is already fierce interservice and intraservice competition over the relevance and prioritization of existing and programmed platforms.

There are big bets to be placed. Is NCO the right horse? The short answer is yes. Of course, there is much uncertainty. NCO will be the product of many interacting forces. The resulting complexity will make its final form as unpredictable as long-range weather. NCO will both shape and be shaped by the character of future warfare and the development of our strategic culture, as well as by the reactions of potential adversaries to our developing style of fighting. That is why NCO should be allowed to evolve without the constraints of a precise script that would enslave it to inevitable errors in the details.

The information age has set off an avalanche of fundamental change throughout society. The best-studied effects are still unfolding in the transformation of the economy. For decades, people have been thrilled, made apprehensive, enchanted, or unsettled, but always dazzled, by the pace of technological change. Below the surface, however, lost in the commotion of new discoveries and gadgets, something much more significant has been emerging—a new economic order.[1] Because of networking, the basic rules of economic behavior have been turned inside out. New laws of *increasing* returns describe effects that either had not occurred previously or were masked by incorrect industrial-age assumptions. During the

Industrial Age, economics, warfare, and other human behaviors were radically transformed. The current transformation promises to be equally momentous.

The central issues of this paper are introduced below; each is further developed later in this discussion. Consensus on these issues can facilitate a smooth transition to network-centric operations.

High Stakes. NCO will be the essential tool of future naval expeditionary operations. What is not so clear, however, is whether it will appear on schedule or within the specifications of any grand plan.

NCO Is Too Big and Too Complex. Complex adaptive systems emerge or evolve over time after the resolution of innumerable trade-offs related to technologies, societies, economics, people, and the environment—all under conditions of irreducible uncertainty. The key to the Navy's transition to NCO will be to set favorable initial conditions and establish simple rules and to avoid hopeless attempts to prescribe the final design.

NCO Will Change Our Military's View of Things. When considered in the context of NCO, age-old questions of warfare will lead to different conclusions about doctrine, platforms, training, and culture. This is evidence that NCO should be placed in a separate hierarchy, which is not in competition with programs and infrastructure (including platforms) which are really subset issues. Since some subset issues require long-lead decisions and resource commitments, there is some urgency for moving ahead with NCO.

Immediate Value and Paybacks. An important feature of NCO is that while it is being implemented, it promises immediate benefits in small-scale, littoral operations. Unlike futuristic initiatives that require large investments and decades of development time, NCO can enhance the combat effectiveness of *current* forces. As it evolves, NCO will become a significant factor in large theater operations.

Sensors Are the Biggest Obstacles to NCO. NCO depends on networked sensors, people, and weapons. Sensors are currently out of synch with the progress of communications and weapons. This major flaw could obstruct the maturation of expeditionary warfare, which again is cause for urgency.

Expeditionary Sensors Are Different. Historical models are unlikely to produce the sensors that will enable NCO and sustain viable expeditionary forces. The Navy must field new devices that break the constraints of platform-sponsored and mounted sensors. In parallel, the Navy must also ensure that expeditionary needs are included in national sensor-development criteria.

Expeditionary Sensors Should Be Funded. The defense industry excels at the design and construction of complicated things like high-technology sensors, and the short-term payback for fixing sensor deficiencies is large. The Kosovo bombing campaign offers a straightforward justification for financing sensors that will restore, or boost, the combat performance of current platforms. "Better sensors along with improved processing and dissemination capabilities are needed to provide a capability to counter any future adversary."[2]

Given the Right Conditions, NCO Will Take Care of Itself. As a concept, NCO is vague, and as a program it would be too big for funding in the traditional sense. There is a better way. It is fortunate that complex systems can evolve without too much attention (engineering) from us.

HIGH STAKES

Network-centric operations constitute a tool or a means to conduct warfare in the information age. NCO exploits the new, simultaneous technological leaps in sensors, networked communications, and precision weapons and in their application to the problems of expeditionary warfare. The net result should be an unprecedented ability to influence directly events on land from the sea. Furthermore, these developments take place at a time in history when the world's military problems increasingly arise in scales and locations that lend themselves to expeditionary operations. To some, the Navy's role may appear to be less glamorous and focused than during the Cold War years. The value and utility of U.S. forces may rise or fall in this new environment; however, relative to other U.S. services, naval expeditionary forces are poised to become especially relevant.[3] Naval warfare is certainly not a sunset industry. NCO is the essential tool that will allow naval forces to shoulder increased responsibilities and fulfill their potential.

W. Brian Arthur of the Santa Fe Institute compares high-tech business decisions in the information age with an imaginary and extreme form of casino gambling in which the features of the event (including its rules, stakes, and players) do not emerge until the game unfolds.

> Above all, the rewards go to the players that are first to make sense out of the new games looming out of the technological fog. Bill Gates is not so much a wizard of technology as a wizard of precognition, of discerning the shape of the next game. You cannot optimize in the casino of [ill-defined] games. You can be smart. You can be cunning. You can position. You can observe. But when the games themselves are not even fully defined, you cannot optimize. What you *can* do is adapt. Adaptation, in the pro-active sense, means watching for the next wave that is coming, figuring out what shape it will take, and positioning the company to take advantage of it.[4]

The "next wave" for the Navy is NCO.

NCO IS TOO BIG AND TOO COMPLEX

There are only two paths that lead to a network-centric navy: it can be engineered, or it can evolve. The correct choice depends solely on whether the network-centric Navy is a "complicated system" or a "complex adaptive system." Engineered systems are *built*, often to a complicated plan with detailed specifications that reduce a system to simple, manageable parts and subsystems. Complex adaptive systems, in contrast, *grow* from simple specifications and eventually achieve a highly complex form in response to positive and negative feedback between the system's components, and between the system and its environment. When the nature of complex adaptive systems is understood, it becomes clear that NCO is beyond the scope of the most sophisticated engineering methods. While it is true that some components must be engineered and built, the network-centric Navy must evolve and grow.

A complex adaptive system, like a beehive, is an emergent system, with its own identity and with characteristics that result from the interactions of many agents.[5] There is no bee in charge, and no bee understands the nature of the hive. The behavior of a hive, tornado, rain forest, or stock market cannot be predicted by the complete scientific knowledge of a single agent. Similarly, the network-centric Navy will have apparent behaviors, properties, and capabilities that are very different from what might be predicted by a study of its small parts.

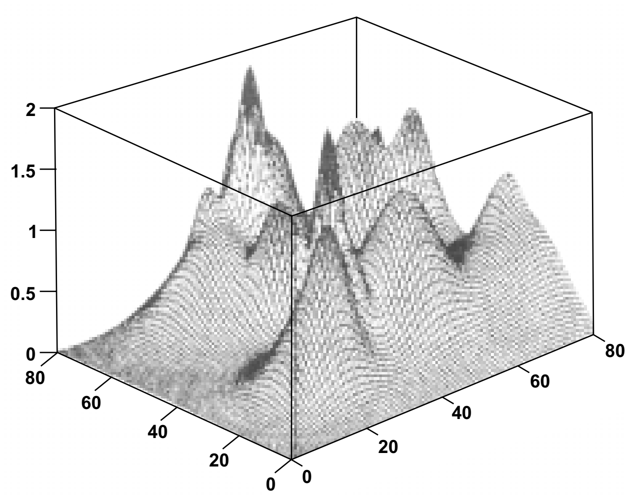
Until recently, human agents have been nearly as uninformed as bees in their practical understanding of how survivable adaptive systems come into being. Ingrained by several hundred years of successful linear, cause-and-effect experiences, human agents are inclined to *think* they are capable of designing something as complex as a network-centric navy. This misunderstanding may result in unnecessarily high risks and large penalties.

Engineering methods have led to very successful and complicated systems, like the modern aircraft carrier and the submarine-based component of the U.S. strategic nuclear deterrent force. Indeed, many components of NCO, particularly sensors, communications links, and weapons, will be engineered systems. It is important that the engineered portions of NCO be limited to enabling functions, such as engineering protocols and standards that foster reliability, security, compatibility, and adaptability. Finally, the engineered components must be flexible and responsive to changing requirements as the larger NCO system evolves.

Engineered systems are optimized systems. System optimization usually focuses on achieving desired qualities like low cost, high speed, or stealth, for example. However, the problem is that the final optimized product is likely to be short-lived in utility, or fail completely, if required to perform under conditions for which it was not created. In nature, evolved complex systems tend to be messy, with redundancies and extra structure that engineers would eliminate if given the chance. The primary purpose of this apparent messiness is survivability, which is achieved through a form of parallel processing that tries all possibilities at the same time and keeps track of all the best results, rather than the few for which human design might try to optimize.

A fitness landscape graphically depicts the many states available to a complex system. On a three-dimensional plot, high-performance, advantageous solutions are represented by local peaks on the landscape. There are many peaks, some better than others, but it is often impossible to predict one's relative fitness with certainty. To further complicate matters, even if a choice could be made to occupy one of the best peaks, the landscape of a complex system is constantly changing. A peak can quickly erode to become a valley, as the environment (culture, adversaries, technology, etc.) continues to change, both independently of and in response to the U.S. military posture. This is how the world works in truly complex biological, business, and military systems.

A FITNESS LANDSCAPE



"Finding a solution, or a peak, is not difficult. What evolution in nature, and evolutionary programs in computers excel at, is hill climbing to global summits, or the highest peaks around, when the terrain is rugged with many false summits."[6]

Fitness landscapes are abstract, and their utility is at best difficult to establish. It is quite possible to never know if the emerging network-centric Navy missed a global peak. The best that can be done is to ensure that an unbiased, evolutionary path is followed as closely as possible, putting faith in the scientific integrity of evolutionary processes. By choosing an evolutionary (vice engineering) approach, the probability is maximized that the "big bet" will be a winner.

NCO WILL CHANGE OUR VIEW OF THINGS

The issue of NCO should be separated from the competitive struggle to define the size, structure, and organization of the "Navy after Next." As elements of NCO become available and routine within U.S. forces, they will provide the context for many important questions—profound questions that will require new thinking if the Navy hopes to take full advantage of the next wave. Some examples are:[7]

- What will the impact be on fixed, heavily defended, or high-risk targets if they are attacked with precision naval "fires" instead of by tactical aircraft? What alternative missions will the aircraft execute, and how will that change the pace of conflict?
- How will important targets be found, as they become increasingly mobile or concealed? The enemy will not present itself in mass formations in front of U.S. firepower. Affordable sensors are needed to perform the dangerous work of discovery, and eventually they will do so with remarkable precision and speed. If abundant, low-cost sensors are built and deployed to find mobile targets, will there be enough sea-based launchers or tactical aircraft to deliver timely fires? Will tactical forces be authorized to engage these targets freely?
- What will be the impact of dispersed and unmanned airborne vehicle (UAV) sensors on the capability, safety, or effectiveness of naval expeditionary forces? How will NCO alter the political and military value of ground forces? If a special-forces team or a company of Marines can detect and monitor enemy movements and activities in its vicinity and then depend on tactical air support at distances that exceed time-of-flight requirements for sea-based fires, then surely the calculus of mission accomplishment versus risk and casualty avoidance (including risk from friendly fire) will be dramatically altered.
- Will smaller, faster, networked ground forces make it possible to better accomplish missions that are currently attempted only with large, heavy forces? To what extent is the current insistence on overwhelming numerical superiority driven by the need for self-protection in the face of uncertainty?
- One physical characteristic of modern warfare is the high rate of fire. Will high rates of fire still be required if precise and timely targeting information is available to complement the smart weapons?
- Logistical estimation and planning seem bent on sustaining rates of fire appropriate to attrition-based warfare. What are the logistics implications of precision fires based on a robust sensor and targeting network? Will the logistics burden shift from munitions to sensors?

- Will improved combat effectiveness make leaders more likely to use military force in the belief that casualties and collateral damage are less likely? Perhaps the deterrent effect of these increased capabilities will reduce the need for actual armed conflict. What conditioning factors will produce either outcome for U.S. military forces in the information age?
- It is expected that networked warfare will proceed with increased speed and intensity, producing effects that extend across both operational and strategic domains. What measures of effectiveness can be used to evaluate U.S. capabilities against adversaries and guide commanders in their assessments of a conflict in progress?

Because of NCO, questions like these will require new ways of thinking about warfare at the operational and tactical levels. They illustrate some of the sweeping changes that have already begun to alter the Navy's fitness landscape. Since many of the conclusions could portend changes that require long lead-times, the Navy should expedite the implementation of NCO to ensure that long-lead issues will be studied in the best possible context.

IMMEDIATE VALUE AND PAYBACKS

Military strategists are sometimes accused of planning and spending for the worst-case and least likely scenarios. Given the difficulty of accurate forecasting and the gravity of failure in war, however, it would be negligent to do otherwise. It is usually assumed that military forces will be adaptable enough to handle any lesser and included scenarios, down through operations other than war. The programs, plans, and preparations are usually big, but most U.S. military activities are scaled down before action. Conditioned by this methodology, some mistakenly assume that NCO must start out as an all-encompassing system aimed at the worst case, major theater war (MTW). A plan to build such a system capable of fighting on an MTW scale would require a resource commitment that threatens numerous military programs and organizations.

Network-centric operations, however, are different. Since NCO is about how people organize and interact, it will be scaleable from the bottom up. Its highest payback is likely to result from its leverage in smaller conflicts, where it is very difficult to reconcile high operational risks and relatively low national security interests. Finally, due to the current U.S. military preponderance, it would appear that the nation will have a decade or two of breathing space in which to nurture and expand NCO capabilities before any MTW conflict is likely to erupt.

An additional incentive for the aggressive implementation of NCO is that it will be an important force multiplier—even in the near term, as early elements of NCO are introduced in the fleet. Some technical elements of the future NCO force, precision munitions and UAVs, have already seen combat. In Kosovo, improvised target localization by UAVs enabled high-altitude air attacks against ground forces with minimal risk.[8] In short, a new sensor input linked to the information grid enabled forces to address a tactical problem that was largely precluded by adverse environmental conditions and risk-avoidance policies. These results should be further analyzed and projected to larger-scale operations.

SENSORS ARE THE BIGGEST OBSTACLES

While it continues to enjoy a substantial margin of conventional military superiority, the United States should pound away at its current most glaring deficiency—the inability to find and attack dispersed targets under such adverse conditions as rain, harsh terrain, and enemy deception. Sensors, because they are today's greatest deficiency, and because of tomorrow's absolute dependence on them, are the common thread between the "Navy of Today" and the "Navy after Next."

The obstacles to sensor solutions are immense because they are both programmatic and cultural. Sensors have long been integrated with platforms. Independent sensor programs are perceived to be in competition with platforms for funding and missions. Yet in the face of new and affordable technological threats to platforms, U.S. forces must not continue to pretend they will be allowed to sail or fly sensors on manned platforms to wherever they are needed in a modern battlespace. Offboard sensors may have presented a threat to manned platforms in the past, but in the future they will likely be the essential enabling factor that saves them from obsolescence. Viewed in this way, there will still be programmatic competition for funding, but progress should be possible when sensor and platforms missions are brought into coalescence. Both are essential elements of NCO.

EXPEDITIONARY SENSORS ARE DIFFERENT

Several general properties of effective sensors are critical to their successful employment: they must be affordable, available, and suitable for expeditionary operations. The uniqueness of expeditionary warfare and its special demands on the sensor system require further explanation.

"Expeditionary" is the defining quality of U.S. naval forces. Today, when an air strike against a distant target may be launched from the continental United States, it is important to understand that power projection by any single means does not qualify as expeditionary. Instead, an expeditionary force provides a flexible complement of military tools that can be speedily applied to a wide spectrum of situations and crises.

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The expeditionary tool-set includes air strikes, but other tasking as well, from humanitarian assistance to air, ground, sea, or cyberspace forces in high-intensity combat. Expeditionary operations are constrained both in geography (size and location) and duration. Geographical size limitations are obvious; theaterwide expeditionary warfare is rarely discussed. U.S. forces deploy theaterwide in peacetime, however, because forward presence is the entry fee for early and meaningful access to potential adversaries in the event of conflict. An explanation of the limited duration quality of expeditionary warfare is that the force must be capable of sustaining its operations either to deter conflict, fight to victory on its own, or gain a military foothold and hold the line until less mobile, heavy ground and air forces can be brought into position. Another time-related point is that expeditionary forces are best used early in a crisis, when initial conditions are often not fully understood and the likelihood of surprising events is high. They must be versatile and adaptable to limit the adverse effects of being surprised.

Sensors, because they are today's greatest deficiency, and because of tomorrow's absolute dependence on them, are the common threads between the Navy of Today and the Navy after Next.

Despite the constraints of geography and duration, there are few restrictions on the intensity of expeditionary warfare, except those that could be imposed by default if the United States failed to organize, train, and equip its forces adequately. Such a failure could render U.S. forces unusable if the adversary is willing to risk high levels of violence.

The expeditionary sensor capabilities necessary to support such a range of activities are substantial. The United States is averse to prolonged attrition warfare and avoidable collateral damage, and expectations in those respects have been raised for future conflicts. The practical utility of expeditionary forces increasingly depends on precision munitions. Better sensors are urgently needed so that aim points for these munitions can be generated for both fixed and mobile targets throughout the battlespace. Specifically:

- National sensor systems optimized for wide-area cueing will not do. Systems that depend on remote-site interpretation or analysis will not succeed if analysts cannot relate the data to the highly fluid context of expeditionary operations. The expeditionary commander and his subordinate forces must be able to adjust the focus, or granularity, of their expeditionary sensors to achieve sufficient situational awareness at all levels.
- To be affordable, reconnaissance and surveillance cannot be limited to a few expensive systems, such as space-based sensors. Existing

microtechnologies should point the way for production of abundant, even disposable, sensors.

- A premise of forward presence is that access to a potential battlespace is developed and refined through peacetime operations, constituting an essential precondition for rapid attainment of operational superiority in conflict. Therefore, expeditionary sensors should be continually in service with all deployed forces, so that the transition to warfare is nearly transparent to the operators. Ideally, in war, the only additional step might be to press a "launch" button. If the naval commander's sensor requirements are to be met, that commander must control them, regardless of which military branch builds or operates the hardware. Even with the best of intentions, beware the difficulties if the supporting organization does not understand the requirement for twenty-four-hours-per-day, 365 days-per-year support to forward-deployed forces.
- A naval expeditionary force requires a flexible system that can change rapidly from routine peacetime operations to open conflict. During peacetime, the sensors must function within the constraints of territorial airspace and sea limitations. In war, the sensor system should smoothly expand to include more intrusive sensors as necessary, to give the commander's networked forces sufficient situational awareness to rule the battlespace.

As effective sensors are introduced, tactical forces will adapt and innovate to use them in ways that enlightened planners could have never prescribed. The creativity of personnel at the operational level should never be underestimated. It would be wise to put robust sensor-to-shooter tools in their hands and then take good notes while they develop and explore the possibilities.

This is not to trivialize the significant work to be done by cross-disciplinary studies based on exciting new efforts in the fields of complexity, chaos, and self-organization. The new sciences will enable significant results on several levels. First, they will assist in the design of system interfaces to present timely and useable information without overwhelming the operators. They will help determine where best to locate the complexity and decision-making elements in naval systems. The theoretical rigor to be gained from these efforts will be as important to warfare in the information age as the study of thermodynamics was to the development of new, efficient engines in the Industrial Age. At a higher level, the new sciences promise broad understandings of warfare. The capability of U.S. forces will be greatly amplified when they are networked, but the most dramatic increases in combat power will come from new ways of thinking about warfare. Since warfare is a complex, adaptive system, clarification and control of the very forces that determine its outcome will produce high payoffs. In short, the goal is to focus on the adversary's high-leverage points with unprecedented pace and intensity, to produce effects that directly impact the adversary's will to fight.

EXPEDITIONARY SENSORS SHOULD BE FUNDED

The national defense system is conservative and risk averse. It is not likely that such a system will easily permit a radical departure from the past, especially for a concept, since, by definition, concepts are incomplete and lack formal proof. The defense system is responsive to competition, however, in that it will generally recognize threats to its relevance, and it permits incremental commitments to concepts or systems that preserve or restore that relevance.

The 1999 operations in Kosovo, for instance, presented a serious challenge to the military's relevance. Regardless of how one interprets that "victory," there was still an undeniable sense of helplessness over the difficulty of dealing with dispersed forces on the ground. It would be unconscionable to ignore this wake-up call, possibly to find U.S. forces in a future conflict with higher national security interests at stake but the sensor gaps unchanged. This is a compelling reason why new sensors should be funded and aggressively developed.

NCO WILL TAKE CARE OF ITSELF

NCO will not be substantially funded, at least in the near term, because as a concept it is too vague, and as a large-scale system it is probably unaffordable. Yet even if cost were no object, it would be a major mistake to view NCO as a completed thought, or as a well-defined program ready to fund, construct, and control. The Navy should accept this and, without breaking stride, *grow* (vice build) a network-centric force. One appealing aspect of NCO is that tremendous combat advantages could accrue from the synergy of self-organization. If this is true for networked warfare, it should also be credible for the Navy's transition to network-centric warfare. NCO will take care of itself, if it is allowed to evolve through a self-organizing process.

Recall from the fitness landscape metaphor that the ultimate aim is to find a global peak, where fitness, adaptability, and survivability are maximized. In nature, and in computerized artificial-intelligence simulations, the proven strength of the evolutionary process lies in its ability to test and compare all possible solutions in parallel and provide feedback of these results to the system. There will always be irreducible uncertainty about the outcomes of complex processes, but evidence everywhere corroborates the fact that evolutionary paths produce the best complex systems. The key to a successful transition to the network-centric Navy lies not in a clear vision of the future but in the Navy's ability to identify and follow an unbiased, evolutionary path.

A coherent strategy is required in order to set the evolutionary process in motion. Some suggestions:

- There is an important role for naval leadership. In biological evolution, genetic information "constrains the self-organizing process to those options which have a high probability of success."[9] Naval leadership must perform a similar function, keeping the learning process alive and the Navy's evolution on a path toward continuous, unbiased creativity.
- To unleash the transition process, start by fixing the sensors. The expeditionary qualities of sensors must be further refined and articulated. Currently available technologies must be leveraged to expedite sensor solutions.
- Continue current efforts to ensure that communications are sufficient, secure, and widely compatible.
- Let the fleet's incremental implementation of sensor and network technologies become an expeditionary-warfare laboratory. Over time, fleet participation will allow many possible solutions to be tested and compared. Encourage, reward, and document fleet experimentation.
- Assess fleet experiments through the lens of new, developing systems-analysis tools and feed the results back into the process. Make the best results prominent (publish them as doctrine and tactics) and allow less useful practices to become extinct.

From complexity theory, it is clear that long-term predictability is an impossible illusion. There is no clear relationship between cause and effect, except over the short term.

Ralph Stacey states that "members of an organization, no matter how intelligent and powerful, will be unable to predict the specific long-term outcomes of their actions. They may specify any specific long-term state they wish to or have any dream, fantasy, or vision they like, but they will never be able to determine the sequence of actions required to actualize them. They may have whatever intention they like, but they will never be able to realize it."[10]

If this is true, what then is the role of leadership in a complex organization? Stacey argues that instead of hopelessly striving for a specific long-term outcome, managers should use their leadership style and power to influence a set of "control parameters" that determine whether their organization will be creative and innovative. "We can identify causal links between control parameters and organizational dynamics. In principle, we can design creative organizations and then rely on them to produce emergent futures."[11] The control parameters that management can influence include: (1) the degree of diversity that is tolerated, (2) the levels of anxiety contained in the organization (in response to internally and externally generated tensions), (3) the number of feedback paths that drive the rate of information flow, and (4) the degree of power difference in the organization and how that power is used.

One of the most difficult things about this whole business is the *illusion of control*, and how important it is to most people that it be preserved. Yet many successful commanding officers will be quick to acknowledge that they have improved their commands' ability to function by giving up some of that control, often by empowering their subordinates. The effects of many leadership techniques will be better understood if they are interpreted as adjustments of Stacey's control parameters. In general, it does not appear that complexity theory will ever lead to new formulae for leaders. Instead, it offers a new way of looking at how complex organizations really function, and a more coherent way of interpreting what successful leaders already do.

The key to a successful transition to the network-centric Navy lies not in a clear vision of the future but in the Navy's ability to identify and follow an unbiased, evolutionary path.

These are exciting times. Every sailor and Marine has an opportunity to be part of something significant, since transformations of this magnitude—from an industrial-age navy to an information-age navy—rarely occur. This particular transition will happen only once. It is still early enough in the process for a thoughtful strategy that promotes an evolutionary and creative approach to NCO to improve substantially the probability of success in this "big bet."

During the evolutionary shift to a network-centric force, the Navy will acquire valuable tools to deal with the disproportionate risks of today's smaller conflicts. It will also learn how to scale its new skills to encompass a large, complex operational battlespace. In the end, we will have built a beehive.

NOTES

1. Kevin Kelley, *New Rules for the New Economy* (New York: Viking Penguin, 1998).
2. Department of Defense, Report to Congress, *Kosovo/Operation Allied Force After-Action Report*, 31 January 2000, executive summary, p. xxii.
3. Relative to other instruments of national power (i.e., economic, cultural, political), sometimes referred to as "soft power."
4. W. Brian Arthur, "Increasing Returns and the Two Worlds of Business," April 1996. Available on the World Wide Web: http://www.santafe.edu/arthur, and in *Harvard Business Review*, as "Increasing Returns and the New World of Business," July/August 1996. pp. 100–9.
5. Beehive and ant-colony analogies are often-cited examples of self-organizational behavior

in biological systems, whereby individual actions are guided by simple rules yet lead to very complex results.

6. Kevin Kelly, *Out of Control* (Reading, Mass.: Addison-Wesley, 1994), esp. chap. 15. Also available on the World Wide Web at http://www.well.com/user/kk/OutOfControl/index.html.

7. Stripped down, these are timeless questions in the annals of military thought. It is hoped the reader will excuse the deliberately leading manner in which they are presented. The significance of NCO is better appreciated when it becomes clear how likely it is to lead to conclusions about U.S. military operations that are different from current practices and beliefs.

8. Warren Ferster, "Troops Get Target Data from Satellite Images," *Space News,* 19 July 1999, p. 3 (on the use of the Joint Targeting Workstation).

9. E. D. Schneider and J. J. Kay, "Complexity and Thermodynamics: Towards a New Ecology," *Futures,* August 1994, pp. 626–47. Also available on the World Wide Web: http://www.fes.uwaterloo.ca/u/jjkay/pubs/futures/tex.html.

10. Ralph D. Stacey, *Complexity and Creativity in Organizations* (San Francisco: Berrett-Koehler, 1996), p. 214.

11. Ibid., p. 217.