# Warfare Analysis: Relevant, Reliable, and Right on Time

*Patricia Sanders*

We live in a world with many warfare challenges, including a national security environment that is increasingly difficult to predict. The many critical issues facing DoD demand the application of warfare analysis. But such an analysis must be relevant to the problem, reliable, and responsive to the immediate need. By meeting these criteria, warfare analysis can and will make a considerable difference. This article explores some of the issues associated with providing the essential warfare analysis requirements of relevance, reliability and timeliness. (Keywords: Acquisition, Interoperability, Logistics, Software, Warfare Analysis.)

## INTRODUCTION

Lately there has been much reflection on the past millennium. A thousand years ago we lived in a world of magic. We didn't know why an acorn turned into and oak tree, why an apple fell to the ground, why the planets wandered among the stars. Nor did we know why children looked so much like their parents. We believed that our lives were influenced by invisible entities and that goblins roamed the Earth. Our wisest men tried to turn lead into gold and searched for elixirs of immortality. We were a big-brained species, but our minds were crammed with nonsense. So clueless were we that we did not even realize it was the Dark Ages.

Of course great civilizations like China, the Middle East, and societies in what would some day be called the Americas did flourish. In those places people studied mathematics, examined the night sky, and tried to peel away the layers of mystery from everyday life. But they worked in isolation. All information was *local*. Toward the edges of maps they drew sea serpents. It would not be until halfway through the millennium that the geographers of the world would begin to realize where, exactly, they were.

What people *did* have, even 1000 years ago, was a tremendous amount of ingenuity. Somewhere along the way, human beings developed a knack for figuring things out. They asked big, tough questions. They didn't have the power to find truth quickly, and indeed they made some great blunders. But over time they seemed to get things right more often than wrong. At first, however, progress came slowly.

Today it is compelling for warfare analysis to get things right—and quickly. As I look broadly at the impact of the external environment on our national security, I note that so much has changed, not just in the past 20 years, but in the last year or two. In the post–Cold War world, we no longer face a single galvanizing threat like the former Soviet Union. Instead there is an increased likelihood that our forces will be committed to limited regional military actions (i.e., coalition operations) in which our allies are important partners. I would characterize the present national security environment in statistical terms by saying that the mean value of our single greatest threat is considerably reduced. But the irony of the situation is that the collective threat that we must deal with, plan for, and counter is both much more varied and much less predictable.

This situation gives us pause in trying to plan intelligently. As we enter a new era for Joint warfare in the 21st century, we want to be able to predict and shape its nature. If we were to travel back to the dawn of the 20th century, would we have foreseen that in less than a single generation the greatest war in history would ignite? Would we have anticipated that in less than the span of a single lifetime we would see the emergence of the airplane, tank, submarine, and wireless radio, which would transform forever the field of human conflict? Or would we have extolled the virtues of the horse cavalry, observation balloons, and the bayonet? Much of the tragedy of World War I stemmed from the inability of military leaders to grasp the implications of change. Their failure doomed an entire generation and led directly to a second and even more destructive war.

Guilio Douhet noted that "victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur."[1] So one task of the warfare analyst is to look into the future. In the next decade, our forces in the field will likely face a wide range of threats, from terrorists to rogue states equipped with weapons of mass destruction to potent regional powers. And beyond that period, we may even face a peer competitor, another power with the resources to challenge us on a global scale.

In such a world, with our considerably smaller forces, we must be prepared on short notice to execute a wide range of tasks, from giving humanitarian aid to disaster victims here and abroad, to filling a peacekeeping role, to participating in the most challenging regional conflicts. General John Shalikashvili, speaking on 24 September 1997 to the National Press Club upon his retirement, explained:

> As a matter of fact, today the difference, or "delta," between capabilities of our military forces and the military forces of those who would wish us ill is greater than at an time in my 39 years of service. And our challenge for tomorrow will be to maintain that delta so that a future chairman, 10 years from now, can come before you and say with the same conviction that ours are the best armed forces in the world, bar none.

But the advantage the warfare analyst has in today's world—versus any other time in history—is that knowledge is no longer local. Our knowledge base is expanding at a staggering rate. More information has been produced in the last 30 years than during the previous 5000. A weekday edition of the *New York Times* contains more information than the average person was likely to have encounter in a lifetime in 17th century England. The information supply available to us doubles every 5 years. More importantly, we are integrating data in more ways, giving them context and thus forming them into information; and we are assembling chunks of information into larger and larger models and architectures of knowledge. The sharing and moving of knowledge is really the key in this new era. Peter Drucker[2] has said that ours is a world in which *knowledge,* rather than labor, raw materials, or capital, is our key resource.

What the warfare analyst must bring to the process is discipline, taking this large knowledge base and applying it rigorously to the key issues facing our national security. More specifically, the analyst must ensure that the correct and most critical issues are addressed—that the analysis is *relevant*. The warfare analyst must also ensure that the insights posed are based on a sound foundation and are credible—that the analysis is *reliable*. Finally, the analyst must ensure that he or she is responsive so that an impact can be made in a timely manner—that the analysis is *right on time*.

## RELEVANCE

For warfare analysis to have value, it must first meet the criterion of relevance. We must direct our energies toward addressing the pertinent questions that will make a difference to the warfighter. The following sections examine a few of the most critical challenges that must be tackled.

### Procurement Issues: What and How We Buy

Our major challenge will be to specify, develop, equip, train, and support America's splendid fighting forces with the weapons and other essential military systems required to meet the projected threats of the early 21st century. These threats range from terrorist actions to the actions of rogue nations, through major urban and theater warfare, and on up to nuclear war. We must recognize that these hostile forces are unlikely to attempt to match overwhelming U.S. superiority on a plane-for-plane, ship-for-ship, or tank-for-tank basis, as was the case in the Cold War model.

Future enemies will more likely use asymmetrical strategies including weapons of mass destruction (chemical, biological, and nuclear) against our troops and infrastructure, even on American soil. They will not need to develop their own weapons. They can simply buy them on the global arms market and sometimes even on the commercial market. They can also purchase weapons training and acquire the skills used in the tactics of global information warfare against our forces and infrastructure.

To counter these threats, the United States must not only actively engage in counterproliferation efforts, but must also exploit its leadership position in advanced technology, especially in the information field. The key to handling likely scenarios of 21st century warfare, as the Chairman and Joint Chiefs of Staff stressed in *Joint Vision 2010*, will be our ability to achieve truly integrated, multiservice operations at all levels and, increasingly, on a multinational basis.

The programs under way today to exploit the potential of information technologies and leverage other advancing technological opportunities will transform warfighting. We want our men and women to be the masters of any situation. In combat, we don't seek a fair fight, but rather the capabilities that will give us a decisive advantage. We want the best-quality people our nation can offer and the best-quality weapons our technology, scientists, and engineers can produce. So it is vital that we carefully analyze what we buy. It has been said that the two greatest threats to weapons systems development are ignorant warfighters and unconstrained engineers. Equally important is the analysis of how we buy.

The companion challenge is how to pay for this required modernization within a constrained budget. The most difficult aspect is that our program must be fiscally executable. For the past several years, the U.S. defense program has suffered from unrealized expectations with regard to modernization. Dr. Paul Kaminski, former Under Secretary of Defense (Acquisition and Technology), likened this dilemma to Lucy and the football in the Peanuts cartoons—never quite there as anticipated.[3]

The solution will require a significant realignment of overall DoD resources to reflect 21st century military needs. To meet the challenge we must fully implement a "revolution in business affairs," both within DoD and its industrial base. Our joint success in this venture will achieve performance gains at far lower costs. To achieve that success the government must take advantage of the technologies implemented and management lessons learned by U.S. industry over the last decade as it returned to its leadership position in worldwide commerce, i.e., we must ensure the quality of our processes as well as our products.

## Complexity Issues

The nature of products and processes demanded by today's global marketplace is changing. So are the products required by our warfighting strategies. Over the past 25 years, the most successful commercial technologies have become significantly more complex. For example, typewriters have been replaced by PCs, and CD players that rely on computer chips and lasers have replaced audio players that were based on Thomas Edison's phonographs. Certainly the advanced technologies upon which Joint Vision 2010 will rely (e.g., low observable masking, smarter weapons, long-range precision capabilities, and information technologies)—all unknown a quarter century ago—are far more intricate.

The future belongs to those who can make sense of the complex, take an idea from conception through the functional integration of many multilayered technologies and disciplines to product realization, and put those technologies and products "out the door" and into the hands of users. Success in this era will occur when different approaches and perspectives are combined to achieve quality, more so in the DoD than anywhere else.

DoD is one of the largest and most complex organizations in the world, with 1.4 million men and women on active duty in the uniformed services and about 800,000 civilians. Every year we recruit about 200,000 new people into the armed forces and separate about 220,000, so approximately 30% of our organization is either coming or going. We are spread out all over the world at some 250 major installations. We operate 550 public utility systems, including everything from gas, water, electricity, and natural gas distribution. We support one of the largest educational systems in the world (126 elementary and high schools), and 300,000 kids attend DoD-run daycare centers!

We tracked 28,000 separate computer systems for Y2K; 2,800 of those were mission critical. Every month we cut about 5 million paychecks and 400,000 bonds and pay about 600,000 travel vouchers and 800,000 contract actions. The Columbus, Ohio, Center for Contracts of the Defense Finance and Accounting Services administers 390,000 contracts and disburses about $43 million an hour.

DoD sustains operations in every time zone, with 115,000 military personnel deployed around the world. And that's in addition to the 200,000 who are permanently stationed overseas. We operate over 400,000 vehicles—everything from sedans and buses to runway sweepers, combat vehicles, tanks, and armored vehicles.

In information technology, we operate some of the world's most advanced computers. And yet, just last year, we moved a number of Burroughs punch card readers to a new mega-center because we are still operating punch cards for some business applications. So we manage an astounding spectrum of technology, making us not only the largest, but probably the most complex organization in the world.

DoD has seen its budget cut for 15 consecutive years, operating today with 46% of the monetary resources it had only 12 and 13 years ago. And, as already noted, about a third of its personnel come and go in any one year. Yet it is an organization that can, within a month, send 60,000 people to the Persian Gulf along with 400 combat aircraft and 500 cruise missiles to carry out a war.

### Interoperability Issues

One specific aspect of complexity that cries out for relevant analysis is a focus on systems integration over platforms, reflecting the public's post–Cold War demands on their armed forces. People want their soldiers exposed to as little danger as possible, and they want their defense bills as low as possible. This means more precision, more stand-off capability, and the ability to integrate at a higher level than ever before. Integration is also important from a budgetary standpoint because it is the vehicle by which DoD will leverage existing technology to create new systems.

Whether you call this vision the "Army After Next," "Forward from the Sea," "Operational Maneuver from the Sea," or "Expeditionary Aerospace Force," the approach to meeting our defense capability needs has changed. Albert Einstein said, "You can't solve today's problems with the same kind of thinking that created them."[4] And my contention is that we need a fundamental shift from platform-focused acquisition to capability-focused acquisition. Despite an abundance of rhetoric about "systems of systems," our entire acquisition process is centered around individual systems or platforms.

Systems of systems are generally not built like an individual system, but rather represent a managed evolution of individual systems. The degree of discipline and rigor called for by the classical systems engineering approach is well suited for individual systems, subsystems, and component, but is considered overly constraining for a large system of systems. A typical single system developed using the traditional approach is characterized by a well-defined end state. Usually it is engineered and developed within a proscribed profile with defined cost, schedule, and technical baselines. When replacing an existing system, its capabilities frequently are "swapped in" to take over in entirety the capabilities provided by a legacy system.

Conversely, a typical system of systems has no well-defined end state, that is, it continues to evolve over time rather than through wholesale capability swap-ins. It has varying baselines, some of which are well defined and some not. The total system of systems is heterogeneous, with tailored incorporation of individual systems.

We now have the technology to achieve "network-centric warfare" from innovations that will flow information not just within platforms themselves but across sensors, command and control assets, and engagement platforms. But technology alone won't provide information superiority. Neither will standards compliance alone equal interoperability.

A change in thinking is required to provide capabilities for Joint warfighters and not just systems for the services. Thus in order for warfare analysis to be relevant, it must be capability focused. It must consider a capability across the entire acquisition process, from requirements development through engineering, test, manufacturing, and fielding. It must also encompass a variety of warfare areas (e.g., theater air and missile defense), digitization of the battlefield, attack of critical and time-sensitive targets, attack of hard and deeply buried targets, cooperative engagement, etc.

## RELIABILITY

If warfare analysis is to be reliable, we must have confidence in the solutions we propose. The following examples illustrate some of the most important and demanding issues that must be addressed to achieve reliability: software development decisions, logistics or supportability reform, and technology exploitation. We cannot afford to make the wrong decisions about these issues.

### The Software Challenge

To put it bluntly, we are in the business of destroying things. In warfare we try to *focus* destruction. In the past we have done this by putting very lethal and highly accurate capabilities in the hands of whoever was doing the shooting at the time. We are now moving into a much more interesting and highly leveraged dimension where the person launching the missile doesn't actually have to see the target. This unprecedented breakthrough in the way we view warfare is called network-centric warfare. We are going to be sharing information across a network and still be able to attack and destroy an opponent. This will dramatically improve the survivability of our own forces.

Considering also that our situational awareness will have to be 3 or 4 orders of magnitude better than that of our opponents, we are focusing on "Information Dominance." A new breed of "knowledge warriors" has begun to emerge, recognizing that knowledge can win or prevent wars. This emphasis on Information Dominance is also causing fundamental changes in what is deemed important to our warfighting capability.

Just consider one underlying change affecting traditional aerospace, namely a transformation from a primary focus on "aluminum bending" to increasing involvement in large-scale electronics system integration. The fraction of electronics in defense equipment has increased from about 1% in World War I to about 5% in World War II to 45% today and growing. Correspondingly, about 10% of the weight and a third of the cost of modern combat aircraft are attributable to electronics and related components. Principal among the latter is software, which weighs nothing but can cost inordinately. We have seen nothing like the headlong rush to software since the similar rush to electronics after World War I. The average automobile of today has more software in it than the first Apollo spacecraft to arrive at the Moon 30 years ago.

During the Gulf War, television cameras, ravenous for dramatic visuals, focused on F-14s roaring off the decks of carriers, Apache helicopters swooping over the desert, M1A1 Abrams tanks growling over the sands, and Tomahawk missiles singling out their targets. Pieces of hardware became overnight stars. But the real star was the invisible software that processed, analyzed, and distributed the data. Software is changing military balances in the world. "Stupid" bombs can become "smart" by the addition of retrofitted components that depend on software for their operation.

It has been predicted that by 2002 DoD will spend more than $20 billion annually on software development for weapon systems, information technologies, and command, control, communications, and intelligence systems. This does not include software development for personnel, management, and nontactical systems. It was estimated in 1995 that DoD would spend $42.5 billion on computer systems, of which $35.7 billion would be on software, and about 66% of that on software maintenance. These figures illustrate the increasing reliance on software for warfare in the information age. Some, in fact, predict a future in which military hardware procurement becomes secondary to software purchases.

There is a flip side. Information or knowledge superiority may win wars, but that superiority is exceedingly fragile. In the past, when you had 5000 tanks and your enemy had only 1000, you had a 5:1 superiority. In an information war, you can have a 100:1 superiority, but success may hinge on your software. It doesn't matter how much speed, stealth, or armor plating we have; we won't succeed if the software doesn't work.

Unfortunately our overall track record for producing quality software is underwhelming. General Randolph, when he was the Commander of Air Force Systems Command several years ago, used to say that DoD had a perfect record on software development: We never got it right. After talking with him recently, I can tell you that he has not changed his mind.

According to the results of a 1995 study[5] on U.S. software development reported by the Standish Group:

- Only 16% of software projects were expected to finish on time and on budget.
- In larger companies, only 9% of the software projects will be completed on time and on budget.
- An estimated 53% of projects will cost nearly 190% of their original estimates.
- Projects completed by the largest American organizations have only 42% of the originally proposed features and functions.

One anecdote has it that if software engineers made automobiles, your car would occasionally die on the freeway for no reason and you would accept this, restart, and drive on. Occasionally, executing a maneuver would cause your car to stop and fail and you would have to reinstall the engine. For some strange reason, you would accept this too. This sort of reliability might be adequate in a word processor, where the consequences are mere nuisance or frustration. But it is totally unacceptable in a weapon system or where safety is a major consideration. After all, a soldier without a weapon that works is at best a tourist, and more likely a target.

So we must have reliable analysis of the requirements for our software; reliable analysis of the development architecture; reliable analysis of how commercial off-the-shelf software could be employed; reliable analysis of the software maintenance concept; and certainly a reliable analysis of the cost of software failures.

## The Logistics Challenge

The magnitude of DoD's supportability issue is enormous. One of our real challenges is to manage about 70 years of technology at any one point in time. We operate aircraft daily that were designed back in the early 1950s, and we still have to maintain them, buy spare parts for them, and keep them updated. At the same time, we are working on research and development programs for systems that will not be fielded until the 2015–2020 time frame.

Fully one-third of the DoD budget (about $80 billion per year) and nearly 50% of the Department's manpower (1,250,000 military and civilian) is in logistics. To get some perspective, we have 290,000 active military personnel in the combat forces and twice that number of active military in the logistics force. If we examine what happened from 1988 to 1998, procurement dollars fell by more than 70%. Operations and maintenance, on the other hand, decreased by only 16%. On a per-troop basis, operations and support costs grew from $107,000 to $125,000.

In *The Art of War*,[6] Sun Tzu estimated that 60% of military spending was required to cover broken-down or worn-out chariots, horses, armor, arrows and cross-bows, supply wagons, and other support. Things haven't changed much. Although the weapons are different, the high cost of maintaining them is not. The Navy, for instance, estimates that 64% of the lifetime costs of a surface combatant ship can be attributed to operation and support.

The picture is not improving. In the 1970s, operation and support costs typically accounted for up to 60% of a system's total life-cycle costs. For many reasons, not the least of which is that weapon systems generally remain in the DoD inventory much longer than originally planned, operation and support costs as a percentage of total life-cycle costs have been steadily increasing and are now estimated to be 72%.

For all systems, both new and legacy, a significant portion of these operation and support costs is directly attributed to the design decisions made during the early phases of the acquisition process. The major categories of cost drivers include fuel and other expendables, spares (both initial and replenishment), operating personnel, and both maintenance and repair labor, with people being the largest element. But all these factors must be addressed very early in the acquisition process. Reliable analysis is needed from the very beginning to influence the entire life cycle and the total cost of ownership.

### The Technology Challenge

On 2 October 1999, the National Missile Defense (NMD) Program attempted and succeeded at its first intercept. A Minuteman II rocket specifically configured to simulate an enemy ballistic missile was launched from Vandenberg Air Force Base in California and headed west across the Pacific Ocean. Some minutes later, as the projectile rose high over the sea, another missile was launched from Meck Island, part of the Kwajalein Atoll in the Marshall Islands, thousands of miles away. And with a closing velocity of about 15,500 mph, the interceptor—smaller than the chair you are probably sitting on now—distinguished the target from other objects in its field of view and collided with it at an altitude of over 140 miles with a force that obliterated it.

The closing velocity of the NMD Exoatmospheric Kill Vehicle (EKV) and its target was equivalent to covering the distance from Washington, DC, to New York in less than a minute. As remarkable as that is, the road to the hit-to-kill interceptor has been even more extraordinary. The EKV is the legacy of a long lineage of aerospace science and test collaborative efforts.

The United States has worked on antimissile projects since 1946. Our interest in missile defenses increased sharply when the Soviets launched Sputnik in October 1957. The Army's announced selection in February 1994 of a hit-to-kill interceptor as the missile for the Patriot Advanced Capability 3 (PAC-3) Program marked the culmination of a protracted evolution. Its roots can be traced back to the late 1950s when the Advanced Research Projects Agency first concluded that a hit-to-kill interceptor would be feasible. More recently, we have demonstrated hit-to-kill successfully six times in the last year—three times with the PAC-3 missile, twice with the Theater High Altitude Area Defense (THAAD) system, and once with the NMD EKV.

The EKV, despite the velocity, the vacuum of space, subzero temperatures, and decoys and evasive maneuvers, is designed to perform this task that is akin to hitting the tip of a bullet with a bullet. Why? Because in the future, the cost of missing the target by even a fraction of an inch can mean the loss of a city under a mushroom cloud or a cloud of anthrax spores.

The dramatic rate at which capability increases have accelerated during the last 50 to 75 years is fascinating. It took 7 centuries for rocketeers to produce the V-2, yet within 15 years of the first missile attack on London, both the United States and the Soviet Union had operational missiles that could deliver nuclear weapons over intercontinental ranges.

Prior to the 20th century, the rate of capability increase seems to have been constrained by limited theoretical knowledge and a restricted technology base. But as we entered the 20th century, we gained increasing knowledge of complex phenomena through the use of sophisticated technology like supersonic wind tunnels, high-speed cameras, and electronic instrumentation. To this expanding knowledge base was added advanced techniques for manufacturing complicated devices and for producing materials tailored to withstand various forms of stress. Now we need reliable analysis to help us optimally exploit this rapidly developing technology base.

## TIMELINESS: RIGHT-ON-TIME ANALYSIS

The third value dimension of warfighting analysis is that of timeliness. No matter how elegant the solution, no matter how thorough the examination, a study that is not timely has no worth.

Ted Lewis, in an *IEEE Computer* article, made two observations[7]:

1. The trend in time increments between major breakthroughs in technology is decreasing exponentially.
2. If this trend continues, these breakthroughs will soon be occurring continuously at every instant in time: We'll be living in real time.

Although I don't expect that we will reach the limiting condition described by Lewis, I am certain that change is accelerating in politics, culture, and technology.

In 1789, it took George Washington 8 days to travel from his home in Mount Vernon, Virginia, to his inauguration in New York City. The number of days in itself is not significant. The important fact is that this is the same amount of time that it would have taken to travel that distance 1000 years before. It was the age of the horse, and nothing moved faster than a horse—no package, person, or idea. No real progress had been made in transportation in the centuries since Moses or Nebuchadnezzar.

But only 60 years later, Americans could move bulky items in greater quantity and over longer distances in an hour than Americans of 1800 could do in a day, whether by land (25 mph on railroads) or water (10 mph upstream on a steamboat). This was a great leap forward in transportation—a factor of 20 or more—in so short a span of time. And since that fateful day nearly a century ago when Wilbur and Orville Wright left their bicycle shop to achieve the long-sought dream of heavier-than-air flight, humankind has indeed come a very long way technologically. In fact, every year it seems to take less time to fly across the ocean and more time to drive to work!

Even more amazing than transportation has been the revolution in the transmission of information. In 1800, it took 6 weeks to move information from the Mississippi River to Washington, DC, by horse. Sixty years later information moved over the same route by telegraph, all but instantaneously. Since then advances in transportation and communications technology have made the world smaller and smaller. In fact, progress has shrunk the Earth so much that all nations are now within shooting distance of one another.

Nothing marks today's moment in history off from earlier periods more strikingly that the acceleration in change. The sense that events are moving faster is palpable. This acceleration, partly driven by faster communication, means that hot spots can materialize and wars erupt into the global system almost overnight.

The threat is not only rapidly changing but also has considerably more variation than in the past, as noted earlier. We must protect against a situation in which one disturbed person or zealot can hold a large geographic area hostage with a weapon of mass destruction or against a computer terrorist who can unleash a successful attack on our power grid or communications network. The rapid advance in technology now means that our adversaries can purchase commercial off-the-shelf commodity computer technology that a few years ago would have been labeled strategic to our national defense and subject to strict export control. Hence we must work even harder, and quicker, to stay ahead of our adversaries.

So time becomes a critical variable, and time is a component of value. Dramatic events demand response before governments have had time to digest their significance. Politicians are compelled to make more and more decisions about things that they know less and less about at a faster and faster rate.

## CONCLUSION

Let me paint you a picture of a new era in warfare. In the Joint force of 2010 we will be able to detect the launch of a ballistic missile; identify, target, and attack the launch platform; alert all units in the impact area; and attack and destroy the incoming missile—all in a matter of a few seconds. The ability to transfer information that fast, across service and even national boundaries, in the fog and friction of war using joint language that we all understand will be nothing less than revolutionary.

Achieving this revolution will be tough. But the warfare analyst can contribute significantly to making this vision a reality by addressing the really important issues in today's national security environment in a credible and timely fashion.

REFERENCES


1. Douhet, G., *The Command of the Air*, Coward-McCann, New York (1942).
2. Drucker, P., *Management Challenges for the 21st Century*, Harper Business Press, Scranton, PA (1999).
3. Kaminski, P., "Sustaining the U.S. Nuclear Deterrence in the 21st Century," *Defense Issues* **10**(99), available at http://www.defenselink.mil/speeches/1995/s19950830-kaminski.html (accessed 25 Apr 2000).
4. *The Quotable Einstein*, Princeton University Press (1996).
5. *Chaos*, Standish Group Report (1995), available at http://www.standishgroup.com/chaos.html (accessed 26 Apr 2000).
6. Sun Tzu, *The Art of War*, Oxford University Press, New York (1988).
7. Lewis, T. G., "Living in Real Time, Where Will the Brain Power Come From?" *IEEE Comp.* **28**(10), 8–10 (1995).


### THE AUTHOR

PATRICIA SANDERS is the Deputy Director for Test, Simulation, and Evaluation at BMDO. She serves as a Senior Technical Advisor to the Director and supports missile defense acquisition and technology programs in test and evaluation, analysis and simulation, and technical risk assessment and management. Dr. Sanders' 25 years of experience with DoD includes positions as Director, Test, Systems Engineering, and Evaluation in OSD (Acquisition and Technology); Director, Land Forces in OSD for Program Analysis and Evaluation; Staff Specialist for the Director of Operational Test and Evaluation in OSD; Deputy Director for Analysis, U.S. Space Command; Science Advisor to the Command, Control, Communications, and Countermeasures Joint Test Force; and Chief of Modeling and Simulation at the Air Force Operational Test and Evaluation Center. She has a Ph.D. from Wayne State University; her government career was preceded by university faculty positions. Dr. Sanders is a Fellow of AIAA, past president of ITEA, and past member of the Board of Directors of the Military Operations Research Society. Her e-mail address is patricia.sanders@bmdo.osd.mil.