It's Not About Mousetraps—Measuring the Value of Knowledge for Operators

By FRANK B. STRICKLAND, JR.

For decades to come . . . many of the best military minds will be assigned to the task of further defining the components of knowledge warfare, identifying their complex inter-relationships, and building the "knowledge models" that yield strategic options.

—Alvin Toffler and Heidi Toffler,
War and Anti-War: Survival at the Dawn of the Twenty-first Century

The National Reconnaissance Office (NRO) builds, launches, and operates systems which collect information from space. It responds to requirements from the Joint Staff, CINCs, DOD agencies, Central Intelligence Agency, National Intelligence Council, operational and service intelligence elements, Department of State, and other members of the intelligence community.

In this maelstrom of requirements, systems developers such as NRO can begin to believe that the end game has more to do with *mousetraps* (systems) than *mousing* (customer needs). This tendency is exacerbated in a culture like NRO's where some of the best and brightest engineers are attracted by elegant technical solutions that underpin all NRO operations. This is a danger similar to the criticism of earlier high definition TV which Nicholas Negroponte made in *Being Digital*. He asserted that research was misdirected at higher resolution pictures instead of improvements in the "artistry of content." Simply put, in pursuing creative uses of cutting-edge technology NRO must continue to sharpen its grasp of the nature of customer tasks and the attributes of knowledge that enable them. This was the goal of a recent wargame, Forward Focus II, cosponsored by NRO and the Office of Net Assessment within the Office of the Secretary of Defense (OSD).

Wargames provide a technique to determine the degree to which knowledge contributes to achieving operational objectives, the kinds of knowledge required by operations, and knowledge strategies needed to cope with various enemy forces and activities. Games have been increasingly utilized by OSD, the Joint Staff, and the services to explore relationships between information and warfighting. For NRO and other intelligence agencies, wargames also provide a venue to expand the dialogue with operators about operations rather than focusing on specific information systems requirements and technologies.

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Additionally, wargames help intelligence professionals gain insight into the operational art—the culminating point and rationale of all the knowledge requirements of an operator—or what might be described as the military genius to recognize strategic opportunities in the battlespace. However, according to the director of net

Frank B. Strickland, Jr., is deputy director, operational support office, National Reconnaissance Office and formerly was the NRO representative to Air University.

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assessment, Andrew Marshall, past information-related games may have lacked the analytical rigor to dissect and measure the complex interrelationships between knowledge and war. This article will examine one attack on this problem: the Forward Focus value model and its use in measuring an operator's needs for information. Moreover, it will highlight Forward Focus II discoveries and their potential for future warfare. These findings are based on operator preferences and utility measures expressed in a wargame and captured through a multi-attribute utility analysis technique (value-focused thinking) for various operational objectives during the wargame.

Elicitation Technique

The first wargame in the series, Forward Focus I, was conducted at the National Defense University in March 1996. Players defined generic information system attributes for a variety of operational tasks. While the game was fruitful, its methodology contained artifacts from the toys-to-task approach raised in deliberations on intelligence support to operations. That is, operators were to tackle the problem by applying the capabilities of the intelligence system (toys) to operational tasks. A more natural sequence would begin with the knowledge needed to accomplish operational tasks, then reach to find characteristics of intelligence systems that could satisfy them.

Forward Focus I took a step away from the future systems grab bag approach by having operators score system attributes vice specific systems, and an excellent group of players produced data which yielded meaningful results considered within the boundaries of a regional war scenario. For example:

- Players identified timelines as a dominant information system attribute.
- Longer periods of collection access were useful for increasing the responsiveness to operators. Continuous collection over a long time—the intelligence equivalent of a running commentary—seemed less useful.
- Players evidenced a willingness to trade the quality of information for increased timeliness—detail for speed.
- Players indicated that on-line digital archives could often offset the need for real-time collection. They would have to be developed primarily before the crisis. The presence of such an archive seems to facilitate the quality-for-timeliness trade.

In addition to substantive findings, lessons from the Forward Focus I methodology were critical to shaping the Forward Focus II elicitation technique. In the first game operators expressed concern with the vernacular of intelligence collection and the use of that dialect to define operational measures of effectiveness. This challenged the sponsors to identify a means to measure the value of information from an operator's perspective which became a key design goal of Forward Focus II.

The objectives of the second game were defined in 46 analysis questions. These and the Forward Focus series generally are far more than an academic exercise. Games are one analysis technique that contributes to major program decisions on the characteristics of future intelligence architectures. The Forward Focus II objectives supported this aim. They were:

- further analyze the Forward Focus I data and discoveries
- produce analytical data with sufficient quality and depth to support decisionmaking
- discover new techniques to analyze the needs of operators
- improve the working relationship between supplier (intelligence community) and consumer (warrior)

To satisfy these objectives, NRO and Net Assessment required the appropriate analytical framework, one that informed present decisions with an awareness of future value and utility. In 1992 NRO members participated in *Spacecast 2020*, a study mandated by the Air Force chief of staff and managed by Air University. Its goals included identifying high leverage technologies and applications for space systems in the year 2020 or so. It was followed in 1995 by *Air Force 2025*, which broadened the inquiry to examine air, space, and information operations in the far future. A distinguishing feature of both studies was the analytical model used to identify what's-better-than-what from a combatant's perspective. Because Air University includes the Air Force Institute of Technology (AFIT), the studies relied upon AFIT faculty, especially the department of operations research. Based on analytical challenges, potential models for identifying high leverage capabilities and the technologies that could enable them thirty or more years in the future ranged from a most-to-least dear ranking to cost and effectiveness modeling. A simple qualitative ranking was judged inadequate, and insufficient cost data on future systems (including the costs of bringing emerging technologies to fruition by 2020–2025) made precise cost modeling impossible.

Value-Focused Thinking

A fortuitous compromise was found in *value-focused thinking* (or multi-attribute analysis), a technique pioneered by Ralph Keeney which allows preferences to be weighed by decomposing them into attributes or qualities and defining utility curves that describe the utility of an attribute. For example, if the people assigning preferences valued food to meet the overall goal of staying alive, the attributes of food might include smell, taste, texture, sodium content, caloric value, and fat content. Such qualities become quantified in an elicitation process, essentially an extended pair-wise comparison which involves assigning numerical values. Thus the qualities of food must total 1.00 and might be divided as: smell (0.06); taste (0.50); texture (0.04), sodium content (0.03); caloric value (0.20); and fat content (0.17). This reveals that for the evaluators the most important quality of food is taste. To the extent that food means staying alive, taste is the dominant quality. These values (or weights) are quantified by utility curves and distributions that then allow *qualities* and preferences to become *quantities* that can be compared. The relationship among food, shelter, warmth, and oxygen can then be understood for their contribution to staying alive, and taste can be compared as a value to a different attribute, such as the value of "76 degrees F."

understanding the role of knowledge in the battlespace proved a monumental chore

Value-focused thinking allows qualities and quantities to be linked in a single model. This is a technique that requires the elements it uses to be both comprehensive when taken together and as mutually exclusive as possible when separate. Consequently, food and taste cannot be on the same level since taste is a subordinate of food. The highest and best value accrues when analysts work with evaluators to construct a utility or preference curve for each quality by eliciting this data from evaluators. It is not enough to know that taste is dominant. Taste must be analyzed to learn the points at which *how much* or *how good* affect the quality called taste.

A model for the measurement of the intelligence component of operations awaited creation. The decomposition technique that is a prerequisite for constructing a value model required NRO to think about military operations and intelligence from a combatant's position. The analytical team concluded that intelligence, however defined, helped a combatant meet operational objectives and thus should not be the model's aim. By defining the model's objective as "conduct an operational task," the team helped ensure the intelligence component was structured from an operator's view.

With the object defined the next issue was what combatants *do* to meet an operational goal. This elicited hundreds of action verbs which, when grouped by affinity diagramming, revealed that meeting operational objectives required combatants to do three things: *know*, *plan*, and *execute*.

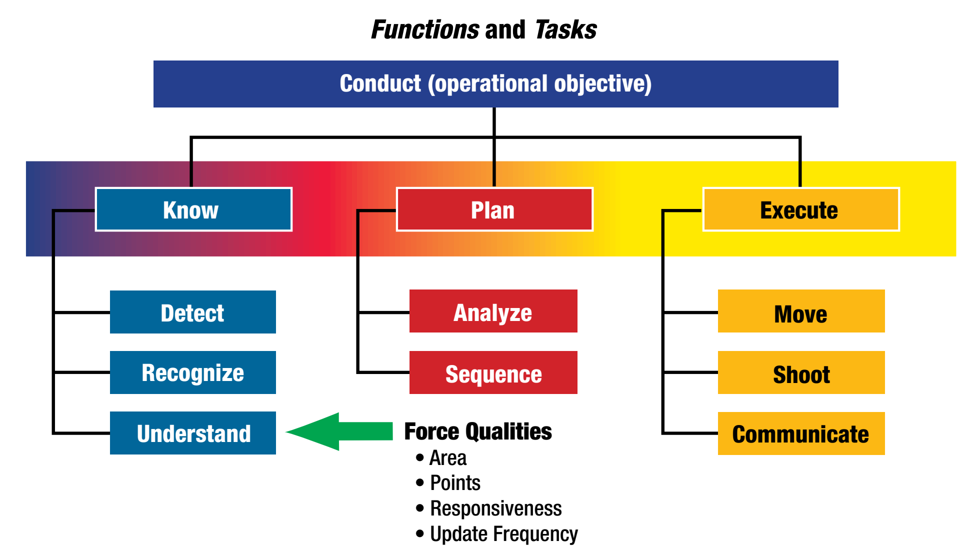
The next major issue became how intelligence contributes to meeting operational objectives. This required a better understanding of what intelligence *did*. From before the days of Sun Tzu, knowing one's own forces and those of an adversary has been a prerequisite for military success. Martin van Creveld, John Boyd, and others have discussed the role of knowledge in warfare and competition. One's knowledge of war rarely reaches certitude, and tradeoffs between certainty and knowledge adequate for effective action must be made continually. Friction and chance are added to a smart adversary's denial and deception operations making *knowing* chancy. The battlespace, despite our best efforts to control it, remains nearly chaotic. Understanding the role of knowledge in the battlespace and its contribution to operational activities proved a monumental chore.

Action Words

Analysis showed that to combatants *intelligence* as a noun is *knowledge* about an adversary and the environment. As a verb, knowledge is *knowing*. The question then became what are the component parts of knowing, also expressed as verbs. Focusing on verbs is important for several reasons. First, they provide a basic understanding of what must be done, and, second, they help avoid seeing the world as either products or product divisions. The model pivots on understanding the component parts of knowing, not on nouns like J-2, signals intelligence, imagery, satellites, or unmanned aerial vehicles. Finally, verbs allow those who use the model to recognize that there are potentially many ways to *do* what must be done and an array of products that might fill that need. The result was a model indicating that the components of *know* were the verbs *detect, recognize*, and *understand*. These action words represent levels of cognition and occupy graded rungs on the abstraction ladder: it is easier to *detect* than *understand*. The Forward Focus II knowledge model emerged. It included the component verbs for *plan* and *execute*, and an example of a utility curve for *responsiveness* appears in the accompanying illustration (figure 1).

Application of the Forward Focus II model in a game required an adversary and a group of players. A wargame adversary is fully characterized through force capabilities, current disposition in the battlespace, and the geography on which it operates. A history of the scenario, the conflict path—though sometimes emphasized in gaming design—is less important than the action-oriented problems blue combatants face. It is ultimately of little value to debate the plausibility of a game scenario in the 2015 time frame. It is doubtful, for example, that the Falklands War was

Figure 1. Military Operations Value Model



gamed decades prior to that conflict. Similarly, it may matter less who a future adversary actually is than that we foresee the possibility that very capable adversaries might arise. A scenario nonetheless does provide boundary conditions for the experiment and the conditions which result. In the case of Forward Focus II, a different fight or problem under different conditions may have changed the knowledge required for operations.

The Forward Focus II scenario had one principal criterion: construct an initiative-oriented regional competitor with robust long-range precision strike capabilities. NRO developers wanted to capture, as far as a wargame can, the dynamic of combat operations in which offense, defense, and planning occur simultaneously. This was achieved in large part by equipping the adversary with substantial theater ballistic missile and long-range fighter/bomber platforms with weapons of mass destruction (WMD). To help players focus on the adversary and not fight the scenario, actual countries and other geopolitical issues were avoided although real geography was used to avoid the investment in a synthetic geophysical environment and in familiarizing players with it.

While the elicitation technique and scenario are essential to a good wargame, the knowledge of the players is by far the most critical component. This was especially true given the complexity of this technique and effort required to complete the value model for any one operational objective.

Forward Focus II players provided a wealth of operational experience. Their intellects and creativity gave purpose to an elicitation technique that otherwise would have been just another interesting model.

Participants were chosen by name and invited based on warfighting experience, knowledge of the operational art, and combat arms specialty. The aim was that the group represent expertise across the combat arms disciplines. The thirty soldiers, sailors, marines, and airmen—grouped into theater, land, sea, and air cells—came from Air Combat Command, Carrier Group Three, 101st Airborne Division, 9th Bomb Squadron, 8th Special Operations Squadron, and the Special Purpose Marine Air-Ground Task Force (X). Operators currently serving in program analysis and planning positions with Congress, OSD (Strategy and Requirements), the Joint Staff (J-8), service staffs, U.S. Army Training and Doctrine Command, and National Imagery and Mapping Agency also took part. In addition, senior engineers from the aerospace industry participated so they could experience an operator's perspective. The senior player and theater cell leader was a retired general and former member of the Joint Chiefs.

Over the course of three and a half days the Forward Focus II players scored the model for twenty operational objectives (military tasks). These objectives were adapted from the unified joint task list and defense planning guidance scenarios. They were selected to represent a range of land, sea, air, and special operations tasks that would be high priority against the Forward Focus II adversary which included destroying the capability to deliver WMD, suppression of air defenses, identifying/countering the main advance of ground forces, countering special operations attacks on friendly airfields, and conducting an amphibious landing.

Marshall's injunction to the developers included overcoming the paucity of quantitative data traditionally produced by a game. The challenge was met. Players produced 20 weighted models of specific attributes required of any knowledge system with dozens of associated utility curves. This quantitative data illuminated other data as player comments and rationale were examined in the context of stated preferences and the utility curves that quantified the specific value they ascribed to an attribute. Among the findings were insights into how operators view knowledge apart from platforms, sensors, and technologies; how knowledge is generated and battlespace analyzed to direct its gathering; levels of cognition required to *know*; the preference and utility for qualities in the time domain; and a theory of how target objects and associated knowledge values may be grouped into three categories.

Preferences for *know*, *plan*, and *execute* confirmed that knowledge is critical to combat operations. In fact, for problems posed during the game the average value of *know* for operational tasks was nearly equal to that of *plan* and *execute* combined. Those who might rush to judgment aside from the boundary conditions previously cited should be cautioned. The fact that knowledge is a decisive component of war is supported by thousands of years of military history. However, the Forward Focus II model, being platform-and sensor-independent, helped emphasize the value of an operator's organic ability to sense and analyze the battlespace, or more crucially, a warrior's intellectual process for gathering, sorting, deciding, and acting on information.

Analytical Frameworks

All knowledge is not a product of non-organic collection and analysis. In doctrine, operators discern much about the battlespace for themselves by applying analytical frameworks such as mission, enemy, troops, terrain and weather, and time available (METT–T). Player responses indicate that much is gained by integrating METT–T into any definition of operational information needs. Operators use METT–T to develop knowledge, but the Forward Focus II players indicated a further application—guiding the collection of missing knowledge. One can note another verity of warfare as timeless as METT–T: any need is weakness. Thus, the need for knowledge makes one vulnerable to age-old deception/denial measures as well as future information warfare techniques.

knowledge gathering was defined as many small areas and points located in an extremely large threat ring

By applying METT–T during Forward Focus II, operators characterized a much different battlespace than the tens of thousands of contiguous square nautical miles often reflected in post-Desert Storm discussions. Players approached operational goals by identifying signature objects. These are frequently a subset of objects in a larger unit that, when located and identified, indicate the probable status of an entire unit. The presence of mobility and countermobility equipment, for example, may indicate the combat unit and location an adversary intends to use to commence a new offensive. Other signature objects such as armor can theoretically be anywhere in the battlespace. However, by overlaying the METT–T template large mechanized units are more likely to be found in some locations than others. For instance, without the benefit of satellites, the U–2, or other such collectors, the men of the 1/21st were told they would be in the enemy's path in early July 1950, as Max Hastings indicated in *The Korean War*. This was based on organic knowledge—contact with North Korean forces—and application of METT–T. In this case, the routes to the south for a large mechanized force were few and obvious.

An adversary with long-range missiles and the ability to move rapidly is a larger challenge. For the game, threat radii from surface-to-surface missiles and long-range fighter-bombers created a battlespace in excess of two hundred thousand square nautical miles. Current surface-to-surface missile capabilities reflect a similar threat while future systems would further expand the threat area (see *Proliferation: Threat and Response* published by the Department of Defense in April 1996). While the scope of the game did not permit a precise delimitation of the battlespace to likely threat locations, operators were clear in using METT–T to delimit searches for all signature objects.

To the extent that long-range precision strike forces are a future threat of interest to U.S. planners, the battlespace must be defined by the radii of threat systems—hundreds of thousands of square miles versus tens of thousands. Theater cell players identified this as the top priority based on the nature of the threat and ability to deliver WMD. As one very senior officer in the theater cell remarked, "Our number-one priority is to destroy red's ability to continue the offensive . . . the CINC's job is to prevent his component commanders from being surprised." Thus, knowledge gathering was defined as many small areas and points located in an extremely large threat ring.

Preferences in the component cells differed notably from those in the theater cell. While knowing about objects and activities in large areas had some value, there was a strong, consistent preference for a combination of points, responsiveness to the need for specific knowledge, and frequent updating of that knowledge. Aside from surface-to-surface missiles and airborne aircraft, forces that traverse the earth's surface do not move very far or fast under the best of circumstances. Likewise, even highly mobile aircraft present large signatures while located at an airfield. These characteristics allowed component cells to focus on specific points of interest that ultimately yield targets. Recall that the theater cell had created the obligation to prevent surprise by *knowing* what the enemy was doing in larger areas.

In considering the observation of objects, the terrain component of an operators' analytical framework should not be viewed in isolation from mission, enemy, troops (friendly forces), and time. These other elements, along with extant terrain knowledge, are all relevant to development of knowledge about an enemy. Even terrain with more or less homogenous surface features, such as oceans or deserts, is still relevant to guiding knowledge collection. For example, an object can be much easier to discern from its surrounding environment in relatively flat terrain than in forests, mountains, or jungles. This distinction from the background would change the sensor granularity required to detect the object, which in turn could have effects on the rate and quantity of collection.

Required collection rates also could vary depending on the platform and sensor if there was a need for increased granularity. However, for those objectives where *area* was valued most in this game, players placed a strong preference on the *detect* level of cognition. This seemed driven largely by the enemy's initiative-oriented behavior and offensive capabilities. For certain objects, operators seemed more interested in timely detection to support strikes than detailed discrimination between classes of objects. That is, when red was on the move and the offensive, blue operators were far less concerned with the type of red tank than where those tanks were that needed to be destroyed. These less agile and higher signature offensive forces caused operators to value knowledge about points on the earth's surface. Points with small and agile signature objects caused players to value higher levels of cognition. Signature objects—such as bridging equipment—could indicate the main axis of attack for red ground forces. These objects, sometimes located at very small geographical points, caused a preference for the *recognize* level of cognition.

Behavior Patterns

Those objectives which required the highest level of cognition often did not contain objects calling for more granular sensing. For example, to understand the red C^3I system mandated observations over time to identify equipment, capabilities, and patterns of behavior that taken together constitute an adversary's C^3I system or process. While behavior patterns can and must be observed in the battlespace in war, identifying von Moltke's strategic opportunities may be based in large part on the observation and characterization of potential enemies during long periods *before* hostile conflict. This suggests that readiness should include a measurement of whether a unit has sufficient prior understanding of enemy capabilities *and behavior patterns* for the mission.

The operational utility for attributes such as update frequency and responsiveness also presented potential issues for knowledge collectors and suppliers. Long-range precision strike forces generally close to engagement quickly, sometimes in minutes. This fact, and the emphasis put on these forces which red possessed in large numbers, drove players to create unusually steep utility curves for update frequency and responsiveness. That is, the value of knowing was often measured in minutes to several hours. After a few minutes, knowing where a mobile ballistic missile erector-launcher was had little value. A surprise was that the operational utility of some kinds and levels of knowledge about other offensive forces was well inside traditional definitions of timeliness. The preferences and stringent utility shown for time during this game suggest that all data providers reconsider what they should gather and how it should be delivered. Systems that collect large quantities of data over longer periods may not be operationally effective against needs for more timely data. Again, Negroponte's admonishment is applicable. Technological increases, such as wider and cheaper bandwidth which permits the delivery of more and more bits, does not necessarily increase operational effectiveness. A more complete measurement of timeliness issues would consider the time required by operators to develop knowledge from data and act on it.

Analysis of all models created for the game also yielded a theory on target characteristics and the knowledge required by class of target. This theory drew on observed similarities in values and preferences for different objectives. These similarities—and a reference to the "timeless verities" of warfare outlined by Trevor Dupuy—made it possible to postulate the characteristics of an object independent of its physical manifestation in the scenario. For example, there seemed to be an object-to-value linkage and an object-to-level of abstraction linkage which remained more or less consistent in the game. Thus, the timeless characteristics of targets in war may be mobility, lethal range, and signature. Mobility is the ability to quickly close to engagement. Lethal range is that at which force has deadly effects. And signature is the degree to which an object is discernible from the background environment.

Arrayed on an x-y-z axis, eight specific types of forces emerge, each defined by extremes (lows and highs) in lethal range, mobility, and signature (figure 2). Historically, more threatening

Figure 2. Combinations of Characteristics

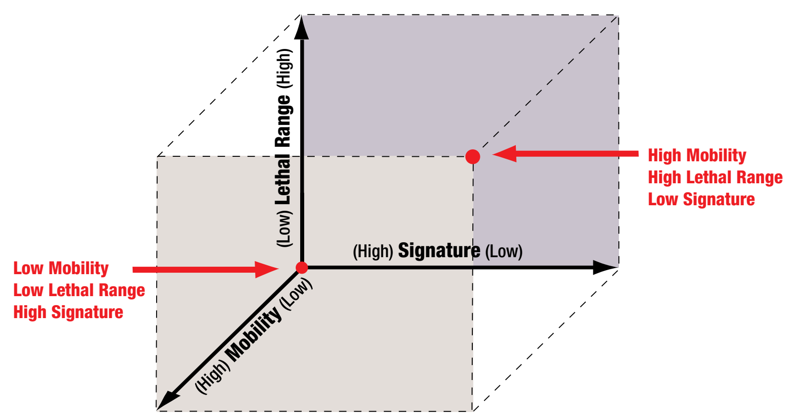


Figure 3. General Target Characteristics and Information Needs

	Agile Attack Forces		Control Forces		Enabling Forces			
Mobility	H	H	H	H	L	L	L	L
Lethal Range	H	L	H	L	H	H	L	L
Signature	L	L	H	H	L	H	H	L

	Agile Attack Forces	Control Forces	Enabling Forces
Access	Theater	Sectors	Global
Cognition	• *Detect*	• *Recognize*	• *Recognize/Understand*
Amount	• Areas	• Points	• Points
Update/Response	• Minutes	• Fraction of Hour to Hours	• Hours to Days

forces are characterized by high mobility (able to rapidly move to effective engagement range), high lethal range (able to outreach opponents and strike them quickly with lethal force), and a low signature (difficult to detect for various reasons). Such forces seem to have consistent values and drive preferences for specific kinds and levels of knowledge. For instance, a force that can rapidly close to engagement does not permit much time between detecting objects and reacting. Objects in such a force have the highest utility for attack. Hence, the value and characteristics of knowing about these objects may remain as constant as their force qualities.

Thus it may be that, regardless of the scenario, three classes of objects emerge with similar information needs as shown in figure 3. Objects with high lethal range and low signature could be identified as agile attack forces. These forces are offensive by nature and may require detection of signature objects within an enormous area in very short timelines. Other forces, such as those with high mobility yet high signatures, allow more focused knowledge gathering over slightly longer periods. A final category of force is found to have consistently low mobility or none at all, such as infrastructure objects. These may require higher levels of cognition over a far longer time to reach the necessary level of understanding. Classifying objects and associated information needs in this way may be of value to analyzing alternative future threats and knowledge strategies necessary to combat them.

The United States is not the only nation studying these matters. Indian Brigadier General V.K. Nair noted strategies for frustrating and deceiving the knowledge component of the kinds of operations demonstrated by the United States with its coalition partners during Desert Storm in his volume on *War in the Gulf: Lessons for the Third World*. Boyd's OODA loop—observe, orient, decide, and act—applies to periods between hostilities as well as war. Potential adversaries have observed our performance and are likely already reacting.

Neither gaming nor other synthetic environments can fully replicate war. However, games are useful for collaborating with operators to determine and measure the knowledge component of warfare—a study of mousing, not mousetraps. As such, they are an integral component, along with requirements processes and technological research, to improving the ways and means of joint warfighting inside an adversary's strategic OODA loop. Over time various games can provide both data and insights that support a more precise understanding of knowledge in warfare and thus aid the planning of future knowledge architectures. As Andrew Marshall noted, Forward Focus II "shows real progress in developing a means of evaluating the relationship of information to battlefield operations." Progress continues. **JFQ**