Entropy-Based Warfare:

Monitoring air strikes, *USS Enterprise*.

U.S. Navy (W. Pendergrass)

Modeling the Revolution in Military Affairs

By MARK HERMAN

A hypothesis first proposed by the Soviets in the late 1970s claimed that a new generation of precision weapons coupled with sensor and information architectures would lead to a revolution in military affairs (RMA). Such thinking is embodied in *Joint Vision 2010*. As the RMA concept develops, the international community must grapple with the impact of advanced concepts like information warfare and the advantages conferred by high levels of situation awareness on the battlefield. Unfortunately, inadequate comprehension of the dynamics of war beyond the attrition-based paradigm has constrained understanding of RMA.

Virtually all current models, simulations, and wargames are fundamentally attrition based. Analytically they often provide quantitative results that support one recommendation over another. But they do not account for many factors that affect the outcome. The few that do quantify factors like command, control, communications, computers, intelligence, surveillance, and reconnaissance (C^4ISR) lack an analytic construct to accurately account for their effects. They simply measure the influence of these factors as increases or decreases in attrition.

The analytic construct behind simulations influences the types of forces built and the kinds

Mark Herman is a member of the consulting firm of Booz-Allen and Hamilton.

Bomb damage assessment, Desert Fox.

DOD

of wars fought. During the Cold War attrition-based simulations strongly influenced acquisition of lethal attrition-oriented systems. While continued reliance on a Cold War attrition-based paradigm is likely to perpetuate large military organizations, a more robust analytic construct could suggest ways to conduct warfare with smaller, more agile forces which are more suitable to implementing RMA concepts. Fundamental to such a paradigm shift is understanding the broader dynamics of warfare and the impact of emerging technologies and techniques.

The modeling paradigm presented here is predicated on the historical view that warfare can be directed against the cohesion of units or states rather than their components. Destruction of the ability of an armored unit to maintain situation awareness, coordinate actions, and apply its will can destroy its effectiveness just as certainly as the elimination of its systems using firepower. In this paradigm, the goal of a force is to disorder an enemy while maintaining its own cohesion.

A physics metric known as entropy can be used to describe disorder imposed on a military system at a given moment. Broadly defined, this metric is the steady degradation, of a system. It is thus the mechanism that measures enemy disorganization and ineffectiveness.

The inability of attrition metrics to account for entropy should raise questions about their validity and the limits of force-on-force paradigms. For example, DOD analytic models run prior to the Persian Gulf War almost universally predicted an attrition-oriented outcome involving heavy coalition casualties that never materialized. An alternate model based on the entropy metric which accounts for various factors affecting cohesion would have more accurately predicted the outcome. The hypothesis is that future warfare, in which our capabilities to affect cohesion will arguably be far greater than during Operation Desert Storm, cannot be adequately modeled using attrition as the primary measure of effectiveness.

Dynamics of Combat

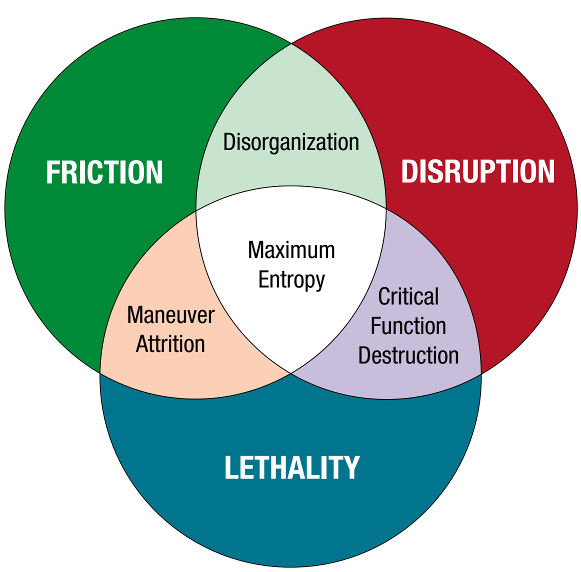
Of the three principle dynamics of combat—force, time, and space—armed strength (force) is the most easily quantifiable and lends itself to analysis by straightforward attrition metrics. Because attrition can be explicitly assessed by counting methods and statistics, it is the basic metric of military success. Theaters of war with high force densities can be reasonably represented using attrition and force ratios, symbolized by the European front in the Cold War when numerical measures of platform strength (tanks, ships, aircraft) defined force capability.

When a model or simulation emphasizes force to the detriment of other dimensions of war it fails to account sufficiently for such other vital features as friction, cohesion, and moral factors. By overemphasizing that element of warfare, Cold War militaries were inflexible and inappropriate for many missions at the lower end of the conflict spectrum. They would be equally ill equipped to handle RMA-style forces. In fact, in a post-Cold War era that puts a premium on flexible forces, the attrition metric is almost guaranteed to stunt development of new concepts and technologies.

entropy is the macro expression for the combined effect of friction, disruption, and lethality

By contrast modeling ignores that a key factor in military strength is unit cohesion: esprit de corps, morale, moral influence, training, and discipline. Within the analysis community no model accurately captures this term. The Joint Staff theater analysis model, though it explicitly quantifies cohesion as a mathematical factor in determining unit capability,[1] omits the Clausewitzian concept of friction. In its classical articulation, friction appears to be absent from all models of unit behavior currently in DOD usage.

Diagrammatic Representation of Entropy-Based Warfare



Attempts have been made to incorporate Clausewitzian friction in models. The RAND Corporation strategy assessment system, for example, has an explicit expression for friction, but it is fundamentally drawn from firepower and weapons performance data such as airpower effects on ground forces.[2] Other approaches have tried to account for friction by building hierarchical constructs which base the behavior of less detailed models on the output of more detailed models.[3] The problem with the latter approach is that the less detailed higher level models are calibrated by minutely specific attrition algorithms; thus the detail being added is simply more exact weapons performance data calculations. Alternate approaches attempt to include soft factors such as intelligence.[4] However, the use of intelligence is almost exclusively limited to applying varying degrees of targeting accuracy to weapon employment, a simple variable of attrition modeling.

Alternate Model of Warfare

Entropy, as noted in one research report on information warfare, is the macro expression for the combined effect of friction, disruption, and lethality on unit behavior.[5] For purposes of discussion, collective expression of current unit cohesion and capability is measured by the entropy level. As organizational entropy rises its capability decreases. A unit with no entropy can realize its full physical potential.

The entropy based warfare concept derives from the fact that a military force must maintain certain cohesive properties based on orderly construction and operation. As a unit loses cohesion, its entropy level increases until, at maximum entropy, it becomes a mob of individuals incapable of coordinating combat potential. The object of war has always been to bend an enemy to one's will, and a means to that end is to defeat an enemy's ability to resist.

The three rings of the accompanying Venn diagram represent the key factors that contribute to unit entropy. Friction comprises those activities the unit performs that increase its entropy level. Disruption includes those activities an enemy conducts to expand the unit entropy level. Lethality is the firepower a unit has to directly reduce an enemy through physical contact.

Where the factors converge, more severe entropy is possible. The intersection of lethality and disruption is the effect destruction of a critical node has on overall unit performance. It could be annihilation of its command staff or surprise attack where attrition is magnified by other factors. The intersection of lethality and friction is the physical loss of personnel or equipment because of breakdown or mines, which prevents a unit from achieving its desired tempo of operations.

Testing experimental systems, Fort Benning.

55th Signal Company (Aaron Robert Kughen)

The intersection of disruption and friction is the use of psychological operations and other information warfare techniques to reduce unit efficiency and cause paralysis. The central intersection where all three factors are coordinated is a more extreme expression of the previous three. In the near future these factors, combined with technological and organizational advances, may offer opportunities to exploit entropy-based warfare.

Implications for RMA

In theory a force based on an interconnected architecture will utilize advanced information assets to understand, locate, and target vital enemy capabilities. Through application of advanced long range munitions and information warfare techniques, an enemy force can be dismembered by coalescing military strength on precisely coordinated timelines from spatially dispersed locations. The platform-based force will find itself disconnected, unsupported, and unable to mass platforms. In this construct, the platform-based force is defeated before it can effectively respond because it masses force much more slowly than its munitions-based counterpart. Hence the munitions-based force finds a major war-winning advantage.

As concepts associated with network-centric RMA have evolved, key features have become evident. The first is that the revolution is information driven and has a high reliance on distributed interactive computer networks. These networks define new RMA military units just as hierarchical command structures defined platform-based units in the Cold War. It is believed that this shared view of the battlespace, enhanced by advanced simulation, will impart time advantages over less aware enemies.

Another key aspect of RMA is its use of precision munitions as the primary mechanism of destruction. The munitions are enabled by information networks that feed coordinates and terminal guidance instructions. In the past, massive munitions were required to account for the geo-location error of the target (like Allied strategic bombing during World War II). With the advent of RMA, both the geo-location error and the area affected by weapons stand in relatively equal proportions. If the position of a target is known, it is almost always hit with one weapon. With timely, updated information, there is a high probability the target is still at its last sighted location, which gives teeth to the phrase *one shot, one kill*. It is a mix of information-driven networks and precision munitions that allows an information advantage to be translated into a step function increase in lethality over a platform-based force. This concept has been called network-centric warfare.

In this new form of warfare, networked computers and databases are manipulated to create a real-time picture of the battlefield that links all echelons through the commander's intent. Force interactions generate effects synchronized in time to inflict high order consequences on an enemy. These effects are captured by the entropy-based warfare paradigm. As enemy elements lose their cohesion, they are struck with overwhelming force to effect final dispersal and surrender. Attrition measures alone don't capture the intent of such conflict. This form of high intensity combat should change the character of the upper end of the conflict spectrum by displacing platform-based warfare of the past with munitions-based, network-centric warfare of the post-Cold War era.

situation awareness is the glue that joins a known past with an unidentified future

The center of gravity for RMA militaries is information and supporting networks. Without information superiority it loses advantages of time and force. Without that superiority, a network-centric force loses leverage to a platform-based enemy. Much as traditional combat occurs on land, at sea, or in the air, cyberspace is the arena for information combat. If an RMA force is unable to protect its networks from hostile responses, it could be vulnerable to older, less efficient, and more robust systems.

Emphasis on interconnected information systems gives information warfare greater direct leverage. With computer networks the way decisions were made and information was manipulated and passed radically changed as machines assumed human functions. This augmentation created opportunities to wage information warfare on timelines beyond human perception across global spatial dimensions. Hardware and software performance becomes a significant set of variables whose impact is not yet clear. The nation that first understands this dimension of the emerging RMA may gain an advantage similar to that German forces enjoyed in France in 1940.

Part and parcel with information warfare is information superiority. An accurate prediction of enemy actions is enabled by situation awareness taken broadly. That entails not only knowledge of locations and order of battle but of the state, location, and cohesion of both enemy and friendly forces and societies. It transcends simple force localization to encompass force capabilities both in terms of systems and the cohesion of the units possessing them. Situation awareness is the glue that joins a known past with an unidentified future. Thus information superiority is a *JV 2010* cornerstone on which all other considerations rely.

Vital to information superiority is space as the location for many components of advanced intelligence gathering and communication systems that support distributed information networks. Accordingly, the weaponization of space and attacks on these systems with lethal munitions will likely be a hallmark of combat in the 21st century.

In short, RMA in its current conceptualization is enabled by information-driven computer networks that confer information superiority, which stresses precision strike, dominant maneuver, information warfare, and space conflict, the key features of RMA. This construct suggests that the ability to quickly coalesce effects in time—as opposed to space—is a critical advantage of RMA. A platform-based force moves at the pace of the platforms. Air platforms can move at mach speeds, but the land and naval platforms move only in the tens of kilometers per hour. The network-centric RMA force moves at the speed of the munitions. Effectively, all munitions move at mach speeds whether glide bombs carried on air platforms or self-propelled missiles. To be efficient this force must acquire, interpret, and act on information in step with the tempo of its munitions.

When effects are coalesced in time, well within the ability of an enemy to react, the capacity to concentrate lethality against enemy critical functions can cause sudden surges in entropy. Vital functions lost to precision strike are often those that could otherwise reimpose order on units, such as senior noncommissioned officers and elements of command. The loss of vital functions and the resulting inability of a unit to heal itself can rapidly decrease capability to resist.

The RMA force still requires platforms for maneuver. But choices are broadened because light airmobile troops supported by precision strike can move at hundreds of kilometers per hour compared to armor-heavy troops of the Cold War. Their traditional drawback is vulnerability to opposing armor elements and anti-air capabilities. Information superiority and the ability to move comfortably within an enemy's reaction capability allows light forces to substitute maneuver agility for the protective qualities of armor. As heavy enemy elements react to maneuver, the information dominant force uses precision strike to defeat them. RMA units can thus mass effects in time more quickly than heavy armor units can mass spatially.

Modeling military organizations with this analytic paradigm shows that critical factors in the RMA equation include an understanding of the impact of information content, synchronization of databases that share that information across networks, and the knowledge advantage of one side over another. Small differences in synchronization can measurably affect performance. Clearly units that move at tens of kilometers per hour are less sensitive to perturbations in synchronization, but those that move at mach speed have less margin for error. If an enemy could degrade network timekeeping, an RMA force could be thrown off with a related impact on performance.

The information network is the center of gravity in network-centric warfare. Portions of it will be damaged by enemy action in combat. The ability of a network to reroute, repair, or bring on additional nodes determines its robustness. If its performance is significantly impacted for any part of the force, information superiority, maneuver agility, and precision strike capabilities should suffer similar impacts. This loss of cohesion and the corollary rise in entropy could see the RMA force incapacitated while it sustains only low attrition.

Seen from this perspective, one is struck by the fragility of the RMA force if underlying information requirements are not met. However, when RMA military requirements are met, the platform-based military is outclassed in the key dimensions of force, space, and time. The use of attrition as the primary measure of effectiveness obscures more than it enables analyses of advanced RMA force concepts. Consequently, it is a woefully inadequate paradigm for evaluating future warfare.

The entropy-based warfare paradigm captures neglected aspects of conflict and allows other dimensions of the warfare equation to impact on a model's computational space. Where attrition-based models primarily emphasize quantity, the entropy-based model creates a more balanced view by emphasizing the physical impacts of attrition and asymmetrical effects of attrition, friction, and disruption on the unit or society.

The entropy-based warfare model uses an alternate, more encompassing metric for combat effectiveness. In addition, the entropy model should apply across the conflict spectrum. Guerrilla, mobile, and conventional war utilize lethality, friction, and disruption with different emphases that rely on strategic factors, relative strength, and character of the forces. When conflict is depicted in terms of friction, disruption, and lethality, the common threads that link various types of warfare become more visible and illuminate where the revolution in military affairs may be going. **JFQ**

NOTES

[1] Booz-Allen and Hamilton, Inc., *Theater Analysis Model* (Tysons Corner, Va.: Booz-Allen and Hamilton, 1981), p. 43.

[2] Paul K. Davis, *Modeling of Soft Factors in the RAND Strategy Assessment System (RSAS)*, no. 7538 (Santa Monica: The RAND Corporation, 1989), pp. 12–15.

[3] Paul K. Davis, *An Introduction to Variable-Resolution Modeling and Cross-Resolution Model Connection* (Santa Monica: The RAND Corporation, 1993), pp. 15–17.

[4] Steven C. Bankes, *Methodological Considerations in Using Simulation to Assess the Combat Value of Intelligence and Electronic Warfare* (Santa Monica: The RAND Corporation, 1991), p. 16.

[5] John Arquilla and David F. Ronfeldt, *Information, Power, and Grand Strategy* (unpublished) (Santa Monica: The RAND Corporation, July 1995), p. 19.