SUMMARY

BACKGROUND

The 1990s have witnessed the dawn of what future historians will doubtless call the Information Age. It is clear that the ability to acquire, retrieve, manipulate, and exchange information has had and will continue to have a profound effect on a host of human activities. Warfare is no exception.

Although it is clear that information will have a far-reaching effect, quantifying or measuring that effect—how to do so—is far from well understood. Such an understanding is important to the Army, particularly at a time when it is spending a considerable amount of its scarce investment capital on establishing Information-Age links across its forces (the so-called digitization of the Army). As it transforms itself, the Army needs Information-Age analytic tools to help it make the best choices possible.

Chief among the analytic tools required are good measures of effectiveness (MOEs) that can demonstrate the value of information in terms of military outcomes. The current set of measures, such as force-exchange and territorial gains or losses, will continue to be useful, but they do not give much visibility to the growing contribution of information. Moreover, they are often calculated with simplistic head-on-head attrition models that omit important processes in which information plays a big role.

PURPOSE

This report develops a limited set of Information-Age MOEs in an attempt to spark the development of many more such measures, which will be needed in the future to quantify the value of information in military operations, including combat. *Joint Vision 2010* posited a series of new concepts of operations for the battlefield of the future: dominant maneuver, precision engagement, full-dimensional protection, and focused logistics. Although these concepts also reflect current operations, *Joint Vision 2010* contended that in the Information Age they become much more powerful—so much so that they are transformed, in effect, into new concepts. We draw on these *Joint Vision 2010* concepts and their further development in *Joint Vision 2020* to frame our exploration of the value of information or, more specifically, of information superiority, which is what the U.S. Army says, in *Army Vision 2010,* it seeks to achieve. In this work, we characterize information as knowledge. Knowledge differs from information in that it takes into account two key attributes of information: quality and value. As defined here, therefore, knowledge consists of relevant and useful information.

APPROACH

We first construct a probability model of knowledge. With this model serving as the theoretical basis for much of what follows, we return to the familiar and more traditional analytic tools of game theory and Lanchester equations to gain insights into the real effects of information on combat outcomes. Then we use these insights, as well as the probability model of knowledge, to develop various analytic relationships that support particular concepts of operations and that incorporate information metrics. Specifically, we develop a new knowledge-based MOE, battlespace control, for the concept of dominant maneuver. We also explore the feasibility of developing new MOEs for stability operations.

GAME THEORY

We employ game theory and then Lanchester equations to assess the value of information superiority, including the possibility of information dominance—i.e., information superiority so complete that it even affects what an opponent knows. The results of our game theory analysis show, among other things, that information makes an overwhelming contribution to the military outcome when one side achieves information dominance over the other, which we define as follows: one side (and not the other) knows the values of the strategic choices available to both sides, and that side also knows which strategy the other side will choose.

LANCHESTER EQUATIONS

The Lanchester equations provide another insightful way of gauging the contribution of information. When a strong information component is added to either the Lanchester square or the Lanchester linear law, it results in what we term a Lanchester "mixed" law. Increasing or decreasing the increments of information available to one side or the other, we found, can powerfully affect the way outcomes of a military engagement are calculated in terms of Lanchester's historical equations. Our calculation of combat outcomes reveals the following: a positive effect for the side acquiring additional information; a negative one for the side lacking or losing information; and formulas for expressing force ratios that change, during the course of the same engagement, from either square or linear law formulations in the beginning to some form of Lanchester "mixed" law in the end.

Our Lanchester-law discussions are, of course, simplifications. More serious combat modeling must resort to simulation. However, analogous effects should be visible in combat simulations if they properly reflect information asymmetries. To put the matter otherwise, our work would suggest that simulations should be tested to assure that they have reflected information asymmetries well enough to bring out the kinds of effects we discuss in this report.

MEASURES OF EFFECTIVENESS FOR COMBAT OPERATIONS

Of the four new concepts advanced by *Joint Vision 2010,* we focus on two: dominant maneuver and full-dimensional protection. For each, we develop MOEs and associated metrics and portray the effects of information mathematically. For these two concepts, Table S.1 shows the following:

- The MOEs;
- The metrics used to calculate these MOEs traditionally, where such metrics already exist; and
- The new, Information-Age metrics we have derived, for the most part by developing a way to calculate the knowledge factor discussed above and including it in every case as part of the metric.

The mathematical calculations show that as the ratio of relative knowledge changes, i.e., what one force knows relative to what the other force knows, outcomes swing in favor of the side with greater relative knowledge. For example, if one side is deploying forces to engage an opponent and discovers that the opponent has blocked certain avenues of approach, those can be avoided, thus speeding the arrival of side one's forces and increasing the amount of operational reach available to them.

Table S.1

Measuring Dominant Maneuver and Full-Dimensional Protection

Concept	MOE	Traditional Metric	Information-Age Metric
Dominant maneuver	Deployment	Items moved per unit of time	Knowledge of enemy attempts to block routes
	Operational reach	Kilometers per unit of time	Knowledge of enemy resistance along routes of advance
	Battlespace control		Size of unit control radius and speed of unit, plus relative knowledge
	FLOT movement	Kilometers	Knowledge of combat capability
Full-dimensional protection	Protection from direct and indirect fires	Hardness, deception and mobility	Knowledge-enhanced hardness, deception, and mobility
	Casualties	Number of losses	Number of losses

BATTLESPACE CONTROL MOE

Battlespace control, which is listed in Table S.1 as an MOE for the concept of dominant maneuver, represents a nontraditional measure made possible, in part, by the knowledge component of its Information-Age metrics. As Figure S.1 shows, we calculate this battlespace-control MOE as the product of a variety of factors: not only a relative knowledge factor but also an agility factor (to take into account a unit's movement speed) and a geometry factor, which accounts for the unit's control radius (itself a product of the ranges of that unit's organic sensors and weapon systems).

MEASURES OF EFFECTIVENESS FOR STABILITY OPERATIONS

In examining stability operations, we sorted among the 16 types listed in current joint doctrine and chose humanitarian assistance as

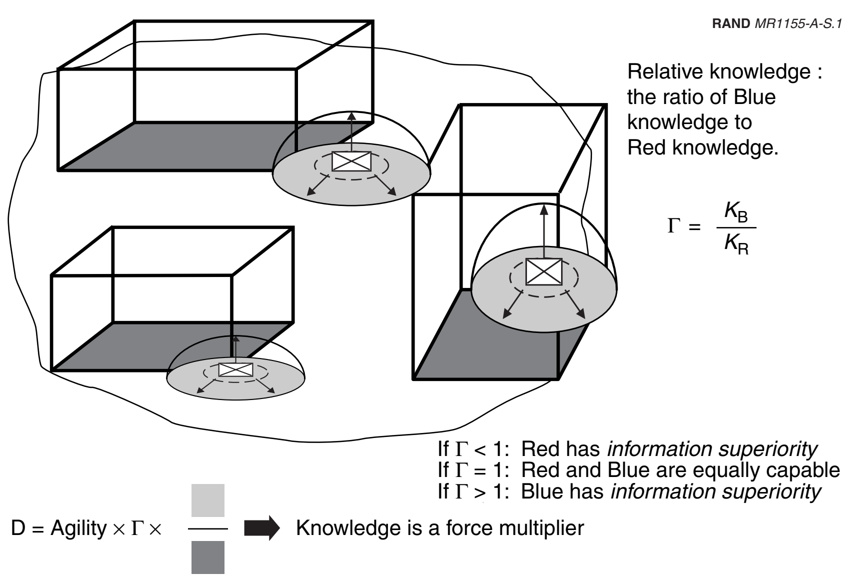

Figure S.1—The Effect of Knowledge

the exemplar for which to develop trial MOEs. We chose this example because the Army has a fair amount of recent experience in such operations, because they typically involve a mix of political and military means to achieve goals, and because they routinely cause the Army to work with many types of actors, e.g., international organizations (IOs) such as the United Nations High Commission for Refugees (UNHCR) and non-governmental organizations (NGOs) such as the American Red Cross.

As we did for the combat MOEs, we drew on the *Joint Vision 2010* concepts as a framework for developing MOEs for stability operations, settling on dominant maneuver as the concept of operations and understanding local environments as the measure. Developing metrics for this MOE (and others like it) is inherently difficult because we are attempting to apply quantitative metrics to qualitative measures. The process becomes even more difficult in addressing humanitarian assistance, because few of the traditional warfighting metrics apply. The metric we develop consists of the contribution of knowledge, as defined earlier, to the degree of understanding of the local environment.

Our approach is to break the "local environment" down into an number of constituent components (e.g., local government, history, terrain), ascertain where knowledge is deficient, and then identify how knowledge can contribute to stability. The theory is that the better the forces understand the local environment, the less likely they are to make errors that alienate the population and the more likely the mission is to succeed.

CONCLUDING OBSERVATIONS AND POTENTIAL IMPLICATIONS

This work on MOEs and associated metrics suggests strongly that information—in particular, information superiority—can have a powerful effect on the outcomes of military operations. The degree of information superiority that one side might be able to achieve over the other is what most needs to be measured in the Information Age. Thus, we have focused in this report on relative measures beginning with relative knowledge, for which we developed the knowledge metric. This metric expresses the relationship between ideal and actual knowledge, for both sides, in military operations. We have also focused here on the need for new MOEs to assess the new concepts of operation being embraced by the Army, as well as on the contribution that information can make to these and other concepts. This work, which is only the first step in a new direction along the road to the future, suggests that development of Information-Age, knowledge-based MOEs is feasible, not only for combat operations but for stability operations as well.