Unit Combat Power (and Beyond)

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Abstract. *With the changing nature of the threat and ongoing transformation, the U.S. Army is very interested in value metrics for its units. A number of combat models and simulations use combat power and/or system firepower scores as a component in automated decision-making and adjudication of combat engagements. An early iteration of this effort resulted in weighted effectiveness indices and weighted unit values (WEI/WUV). Although WEI/WUV fell out of favor as a means to compute combat losses and other outcomes in studies and analyses, many simulations still use some form of firepower scores or relative combat power to assist in making tactical decisions (attack, defend, withdraw, etc.). However, the existing approaches have largely evolved from kinetic-type operations involving lethality and attrition between traditional formations of military forces, and may be irrelevant to current and future operations. This paper will present a short historical examination of the subject, compare new approaches to assessing the relative combat power of units, and make recommendations regarding value metrics. Whereas most previous approaches only measured attrition capability, the new approach incorporates the value of information and sustainment resources. The methodology assesses the contribution of each system to the warfighting functions: intelligence, movement and maneuver, fire support, protection, sustainment, and command and control. The value of the component systems, and consequently the unit, is a function of its operational capabilities. For example, this research will address the residual combat power of a unit where a networked force's operational concept depends on unmanned systems providing situational awareness. This paper will discuss the application of unit value metrics in stability operations as well as conventional operations.*

Purpose.
The purpose of this paper is to propose a revised method for assessing unit combat power and informing decision-making in modern combat simulations and war games.

Definitions.

"Combat power – The total means of destructive and/or disruptive force which a military unit/formation can apply against the opponent at a given time."(1)

"Joint Functions" – The functions include: Command and control, Intelligence, Fires, Movement and Maneuver, Protection, and Sustainment. (2) The interim version of Field Manual (FM) 5-0.1 "The Operations Process", March 2006, labels these functions as warfighting functions.)

"Elements of Combat Power" – The elements of combat power are the joint functions tied together by leadership.

"Firepower score" – In models and wargames, typically a measure of the single round lethality of a particular weapon system. In some models, it is a product of lethality and rate of fire.

"Combat Power Value (CPV)" – In simulations and war games, the value assigned to a weapon system that measures (or estimates) its contribution to combat power relative to other weapon systems. This value may be a whole number or it may be normalized to a specified weapon system.

"Unit Combat Power (UCP)" – In models and war games, the summation of the combat power values of the weapons systems available to the unit. For example, using normalized CPVs:
A combat unit contains 10 systems each with a CPV of 1.0 and 5 systems each with a CPV of 0.4. Thus, Unit combat power = 10 x 1.0 + 5 x 0.4 = 12.0

"Unit readiness" - The ability of a unit to accomplish the wartime missions for which the unit is organized or designed. In the U.S. military, this is measured as a "C" level that measures personnel, equipment on hand, equipment readiness, and training level.(3)

"Strength Value" – Term to designate the unit strength or unit combat power for new or revised methods evaluated in this research.

Background.
A number of current models and simulations, including Vector-in-Commander, use some form of combat power value to make automated decisions about a unit's actions. The derivation of the value is typically a combination of subjective judgment regarding the importance or capability of the system or unit, and an assessment of the relative lethality based on performance characteristic data such as probability of kill and rate of fire. Because of the difficulty of recreating the values for existing systems, and the need for ensuring consistency of values for new systems and units, a research team was formed to investigate this matter and recommend a method (or methods) that would overcome this problem. As a result, they examined several theories of combat and

military operations. In addition, as the changing world situation presents more non-traditional challenges, such as stability operations, irregular warfare, and the threat of weapons of mass destruction, the research team also wanted to ensure that aspects of military capability other than lethality and firepower were considered.

Theories of combat and combat outcomes. Theories of combat and combat outcomes typically include some estimate of relative combat power or force ratio. They also frequently involve subjective factors that cannot be directly measured. These include scientific theories of combat proposed by Clausewitz, Jomini, Bloch, Fuller, and others.

Carl von Clausewitz, in discussing superiority of numbers, advocated achieving success by bringing the greatest possible number of troops into action at the decisive point. Although he acknowledged that Frederick and Napoleon had occasionally defeated forces nearly twice as large as theirs, this was not a common occurrence, and depended heavily on the commander's ability to envision a strategy that placed the troops in the right place at the right time to achieve local concentrations necessary for victory.(4)

Antoine-Henri Jomini, basing much of his thought upon the Napoleonic wars, clearly articulated the requirement to achieve overwhelming force at decisive points on the battlefield. It is also evident from his writings that he assumed that units of equivalent size were essentially equal in firepower and combat capability. He discussed the potential impact of new firearms in an appendix to one of his works and discussed how to best maneuver forces to achieve appropriate force concentration while maintaining some dispersion to reduce vulnerability to artillery. (5) But because he believed that the armaments of opponents were nearly equal (or would soon be because of the rapid adoption of any new technology), he noted that the capacity of commanders and their ability to discern decisive points were keys to success.

M. Jean de Bloch's studies of the various wars of the 19th century enabled him to provide examples of force ratios, discuss the various attenuating factors dealing with leadership, maneuver, entrenchments, and artillery fires, and evaluate the resulting combat outcomes. Bloch saw the advent of new technologies, such as smokeless powder, changing the ability of commanders to apply traditional tactics and thus reconsider ways to take advantage of a favorable force ratio or overcome an unfavorable ratio. In particular, he notes that the British had to achieve force ratios of nearly 7 to 1 and finally 10 to 1 to successfully conduct operations in South Africa during the Transvaal War. Bloch also attempted to quantify the difference between armies of the European powers in both offense and defense. He used a 100 point scale for each of ten factors to assess the moral of an Army. The ten factors were: capacity to adapt to a new situation; composition and recruitment of officers; faculty of initiative; endurance under fatigue and deprivation; discipline; absence of egotistical tendencies dangerous to the general good; confidence in commanders and comrades; age, spiritual condition and manner of recruiting men; confidence in the value of their armament; and courage. He recognized the subjectivity of these factors but believed them to be important given the lessons learned from the Transvaal War and other recent operations. (6)

J.F.C. Fuller saw the potential for achieving extraordinary combat power advantages with the new tank weapon. The ability to quickly strike at critical points, such as command centers, with overwhelming strength, presented new opportunities to overcome the unwieldy maneuvering of masses of soldiers subject to artillery and machine gun fire. He discussed the economy of force with respect to efficiency in combat, thus bringing into play differences in capability for similar systems. He noted that the soldier had to be skillful in the use of means such as hitting power, protective power, and movement. (7) This reference to what we consider lethality, survivability, and mobility is important to our consideration of modern concepts of unit combat power.

F.W. Lanchester is generally credited with articulating mathematical descriptions of combat in his "Aircraft in Warfare: The Dawn of the Fourth Arm – No. V, The Principle of Concentration" published in 1914. He introduced a linear law and a square law of combat to attempt to mathematically describe combat outcomes. Lanchester's laws take into account a factor that can give the combatants on one side a qualitative advantage, be it training or superiority of weapons. (8) (9) Research conducted by Dr. Jacob Kipp indicates that the Russian, M. Osipov, produced work as a contemporary of Lanchester, publishing in the Military Digest in 1915. (10) When WWI trench warfare was prevalent and breakthroughs were needed to achieve victory, Osipov provided explicit formulas for the solution to Lanchester's coupled differential equations; and addressed situations with forces armed with different types of weapons. He was one of the first to use conversion factors to give weight to each type of weapon. Lanchester's and Osipov's work generates discussion and analysis to this day. Many of the current combat simulations still apply some derivation or enhancement of Lanchester's laws. Bonder-Farrell kill rate equations, for example, have roots in Lanchester's work. The work of Lanchester and Osipov also inspired such efforts as the Soviet Union's correlation of forces and the U.S. Army's weapons effectiveness indices/weighted unit values (WEI/WUV) discussed later in this paper.

Current applications.

A number of useful war games and simulations use the theories and variations of unit combat power as the basis for training commanders and staffs, informing course of action planning, or informing force development and systems acquisition decisions.

Military leaders and staff use force ratios and unit strength values in both actual operations and in combat development war games and simulations. As an example of application in operations, for Operation Desert Storm, General Schwarzkopf and his senior commanders wanted air power to reduce the combat effectiveness of the enemy ground units by 50 percent before the coalition ground offensive. Combat effectiveness included measures such as soldiers (and their morale), tanks, armored personnel carriers, and artillery. (11)

In combat development applications, certain war games or highly-aggregated force-on-force models use a force ratio (unit combat power comparison) to determine attrition, and consequently ,victory or defeat in an engagement. In other war games or interactive models, gamers, serving as human-in-the-loop decision makers, use force ratios and percent strength of units to make choices regarding maneuver, application of fires, resupply, emplacement of fortifications, employment of the reserve, and other operational and tactical decisions. In closed form simulations, the simulation must access a set of decision rules (or heuristics) to make reasonable and realistic choices. These types of simulations are generally mid- to low-resolution (i.e. aggregated) combat developments models. Examples of closed-form simulation heuristics are shown below.

Example 1. Make a decision based on remaining percent of initial unit strength to:
- Discontinue attack if strength less than 60%, or
- Merge unit with another when strength falls below 30%.

Percent Strength=$\sum$(current # systems_i * system value_i) / $\sum$ (initial # systems_i * system value_i)

Example 2. Based on force ratio:
- Use joint effects to achieve a force ratio of at least 3:1 before attacking.

Force Ratio=$\sum$(friendly # systems_i * system value_i) / $\sum$(enemy # systems_j * system value_j)
Where:
i is the ith system of n systems in the unit,
system value = combat power value (or firepower score)

In both operational and combat development applications, the analyst uses residual unit combat power to assess outcomes. The question to be answered for both the operational commander and the combat development decision-maker is how well did the force survive?

The success story.

During the Cold War and the last decade of the twentieth century, U.S. analysts worked with wargames and simulation that used combat power values and unit combat power assessments to inform U.S. Army decisions regarding concepts, organizations, and equipment needed to win on a traditional battlefield.

Concepts . The concepts explored included Airland Battle, deep attack, and multiple simultaneous engagements. Airland Battle was an operational concept that emphasized improved integration of the various battlefield functions and improved integration and application of joint airpower against an enemy force. The theory was designed to defend against an attacking enemy by quickly massing effects of direct fire, artillery, and air power, and counter-attacking into the enemy flanks. Engineer mobility (or counter-mobility) operations and a responsive command, control, and communications system facilitated operations. One of the capabilities needed for this effort was a more responsive attack against the follow-on echelons of an attacking enemy force. The concepts of deep attack and the capability presented by "Deep Fires" systems enabled the defender to disrupt or destroy key elements of the follow-on echelon of the attacking enemy and thus significantly reduce the enemy's favorable force ratio at penetration points. The concept of multiple, simultaneous engagements using combined arms was investigated in various models and simulations. It was instantiated by General Maxwell Thurman and his planners and successfully employed by US forces in Panama for Operation Just Cause. (12)

Organizations. The U.S. examined a number of organizational options to respond to the changing nature of warfare during the last 40 years. The Division Restructure Study done in the 1970s examined ways of responding to developments evident in the 1973 Arab-Israeli War. That war implemented new aspects such as anti-tank guided missiles and other more precise weapons that begin to force re-examination of the traditional firepower scores and force ratios.

With the end of the Cold War, the Army embarked on a Force XXI organizational design effort that took advantage of increased firepower on certain platforms, enhanced intelligence and reconnaissance systems, and other combat power "multipliers" to enhance the effectiveness and efficiency of its units while reducing the overall strength of the Army. General Sullivan, the Army Chief of Staff, is quoted as saying the M1A2 is 18% better than the M1A1 because it acquires the target more quickly and can kill it faster. (13) The Modular Force design initiative is the most recent effort to enhance organizational capabilities. The goal is to create unit organizations such that a combat force could be easily tailored to achieve the appropriate combat power and functional capabilities required by the mission. Models and simulations that used force ratios and firepower scores continued to play a key role in the analysis supporting the design decisions. However, as the digitization of the military progressed and the operational effectiveness of military organizations was perceived as heavily dependent upon the network, the question arises whether force ratios and firepower scores continue to be adequate to assess information-age alternative designs.

Systems. In the last quarter of the 20th century, using analysis from computer-based simulations to inform decisions, the U.S. Army successfully updated its principal weapons systems. The key systems were titled the "Big Five." The "Big Five" were the new tank (the Abrams M1), the new infantry fighting vehicle (the Bradley M2); a new air defense missile Surface-to Air-Missile-Developmental (SAM-D), fielded as the Patriot system; a new utility helicopter, the UH-60 Blackhawk; and a new attack helicopter, the Apache AH-64. In addition to these critical capabilities, efforts to counter the Soviet concepts of follow-on echelons led to enhanced artillery systems such as the Howitzer Improvement Program (the self-propelled 155mm M109A6), and development of deep attack rockets and missiles. These included the General Support Rocket System (ultimately fielded as the Multiple Launch Rocket System), and a variety of missiles that included the Army Tactical Missile System (ATACMS). The most recent example of equipment is the Stryker Combat Vehicle. Although Strykers do not have the survivability of heavy armor, their mobility and deployability enable Stryker-equipped units to be rapidly positioned to achieve concentration of force with significantly more combat power than airborne or heliborne infantry.

Problem.

With the challenges of irregular warfare, stability operations, and weapons of mass destruction, and the advent of new military systems that are multi-functional and network-enabled, what is an appropriate approach to determining unit combat power? Is unit combat power still the best way to examine capability to accomplish a given military mission?

Figure 1 notionally illustrates the impact of using weighted total equipment strengths to make decisions in a simulation without also considering specific functional capabilities of the unit. In this example, the unit's intelligence systems have been severely degraded during hour 12 and hour 35. The few maneuver systems for this unit have also suffered losses during those engagements. Even though the unit's total equipment and total personnel strengths are well above 70% at hour 60, the intelligence function is at 50% and the maneuver function is below 60%. The decision made at hour 60 to continue operations without repair or replacement for maneuver and intelligence systems results in additional losses beginning at about hour 65 that put the unit in jeopardy and result in ultimate mission failure.

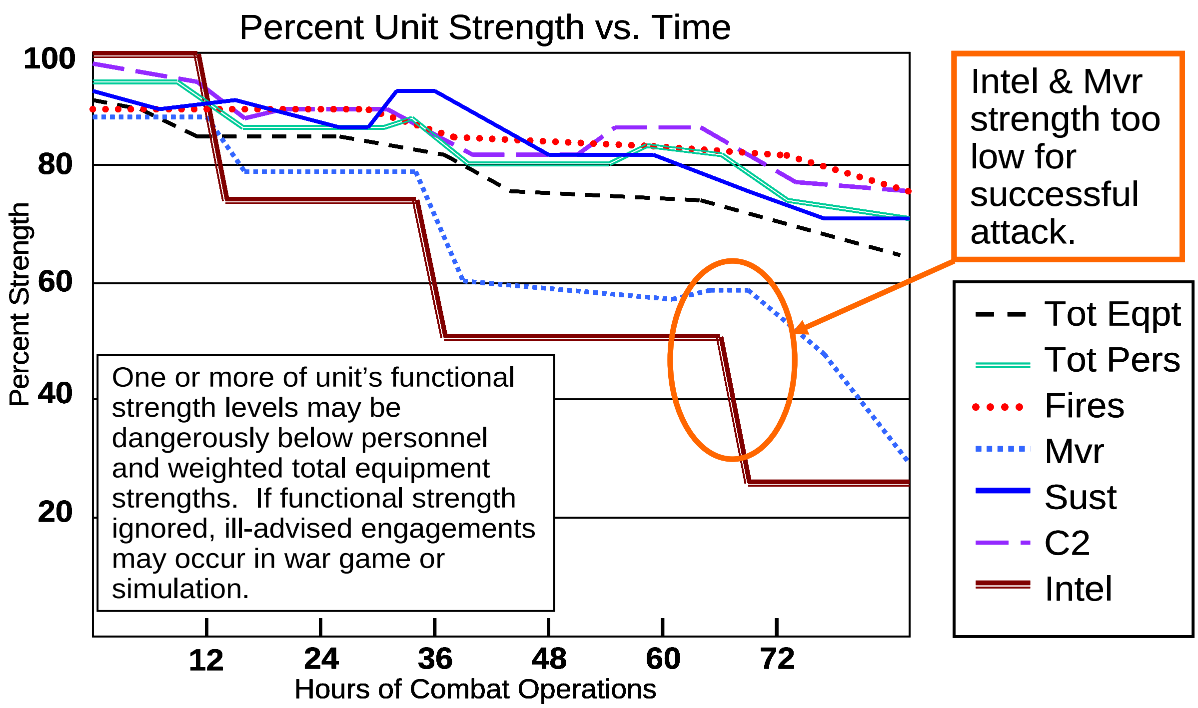

Figure 1. Challenge of Ignoring Functional Capability.

Research approach.

The research approach consisted of a literature review to determine the basis for, and strengths and limitations of previous and current strength value methods. The team then modified methods or created new options that address or transcend limitations of previous methods. Following a comparison of advantages and disadvantages of the methods, the team recommended a method. The intended goals of the research were to reduce the subjectivity of input data, and help the war gamer (or the simulation) make more realistic decisions.

Constraints, limitations, and assumptions.

The research team identified the following constraints, limitations, and assumptions.

Constraints.

- Strength values for unit strength and functional capability must be on a common scale for both friendly and enemy forces.
- Strength values must be understood by the war fighter and war gamer and perceived as "reasonable and realistic".
- The method must account for differences in training or readiness (regulars, militias, home guard, etc.).
- The method must allow both "perceived" and "ground truth" assessments.

Limitations.

- Intangibles such as variances in human leadership, courage, and skills application, or luck or divine intervention are not addressed.

- Strength value is a static measure for a given situation and may not appropriately indicate a unit's capability in a radically different situation, such as drastic changes in rules of engagement or disruptive technological breakthroughs.
- Strength value may not be appropriate for use in aggregated force-on-force models that use a force ratio to determine victory or defeat.

Assumptions.

- Current and future war games and combat simulations will continue to use some strength value to inform gamer decisions, or assist automated decision-making processes.
- Military systems can be associated with one or more specific joint functions.

Literature review.

Soviet Union Correlation of Forces

The Soviet Union's correlation of forces evaluations dated back to pre-revolutionary times and reflected a distinctive Marxist-Leninist perspective. Just as dialectical materialism emphasized the interaction of opposites, the Soviets believed that developments in any part of the world did not take place in a vacuum but were shaped by interactive, conflicting processes. In the Soviet view, those processes were the actions of the progressive forces of world socialism operating against the reactionary forces of "state-monopoly capitalism" or "imperialism". The correlation of forces was a way to assess this process at any given stage of development, either in the global sense or the regional sense. (14) With respect to national defense, a Soviet writer quotes Lenin from his Complete Collected Works, Vol. 36, p. 292, "A serious attitude to the defense of the country means to make thorough preparations and take strict account of the correlation of forces." (15)

Soviet military thinkers applied intense intellectual energy to the discussions of correlation of forces at all levels but especially at the operational and tactical level. Acknowledging the influence of economic, military, and moral-political potentials, writers like S.I. Anureyev recognized the difficulty of measuring all the qualitative factors involved in moral-political potentials, preferring to call them by measures such as "very high" or "low". However, in examining the difference in quality factors for specific military weapons systems, he provided an example of the correlation of forces equation for tanks where the tanks have different capabilities. Using a Lanchester-based approach, the equation is as follows:

$$\mathrm{X} = \frac{N_1}{N_2} * \sqrt{\frac{P_1 n_1}{P_2 n_2}}$$

Where

X = the correlation of forces in tanks.

N_1, N_2 = the quantity of the tanks of the sides 1 and 2.

P_1, P_2 = the probability of the tank of one side destroying tank of the other side with one shot.

n_1, n_2 = the maximum rate of fire of the tank guns for each side.

Assume that each side has an equal number of tanks, however, side 1's tanks have stabilized guns so that the probability of kill P1 = 0.6 and the rate of fire n = 4 rounds per minute. Side 2's tanks are not stabilized and so the probability of kill P2 is 0.1. The maximum rate of fire is 2 rounds per minute for side 2's tanks. The computation results in a tank correlation of forces of 3.5 to 1. Similar equations could be used for other types of systems such as anti-air defense missiles, and could be extended (with additional complexity) to nuclear weapons, as well. (16)

The correlation of forces equations and calculations were especially designed to assist commanders and staff in properly allocating forces to achieve operational missions, and also to assist in determining need for acquisition of more current systems or development of new systems. Acknowledged shortcomings included not evaluating tactics, moral and psychological factors, or environment (weather, terrain).

U.S. Weighted Effectiveness Indices/Weighted Unit Values (WEI/WUV)

The WUV were developed by U.S. Army Concepts Analysis Agency in the 1970s to provide a gross static measure of force combat potential to inform defense resource decisions on system acquisition and force structure. Although now out of favor in the U.S. Army, the description of the WEI/WUV process shown below is considered instructive of this detailed approach. The computations considered the contributions of firepower for weapon systems. The WUV scores for a unit were the sum of weighted WEI scores for the individual effective weapons in a category normalized to the category's representative weapon.

The first step in the WEI/WUV methodology was the categorization of all ground combat weapons that fire and inflict casualties on enemy ground forces. For example, the categories could include main battle tanks, artillery, mortars, armored personnel carriers, attack helicopters, etc. The representative weapon for main battle tanks could be an M60A1.

The WEI methodology. The WEI methodology placed weapons comparable to the representative weapons in a category. Then each weapon was evaluated on the factors of firepower, mobility, and survivability. An index was computed for each factor for each weapon. The factor values were weighted by their perceived relative contributions to the weapon's effectiveness and the weighted indices were summed to produce a WEI.

The WEI formula:

$$WEI = c_f F + c_m M + c_s S$$

Where

WEI = weighted effectiveness index.

c_x = weighting coefficient of each index, for example:
($c_f = 0.60$, $c_m = 0.15$, $c_s = 0.25$)

F = firepower index.
M = mobility index.
S = survivability index.

Each of the factor indices was computed by the following equation:

$$\text{Index} = \sum_{i=1}^{n} Q_i C_i$$

Where:

Q_i = quality scale (ranging from 0-1) of the engineering characteristics.
C_i = weighting factor for the relative value of that characteristic.
n = total number of characteristics considered.

For example, the survivability index S could be calculated using several characteristics, such as armor protection, detectability (presented area), and maneuverability (horsepower/weight). System maneuverability could be weighted as a portion (e.g., C = 0.50) of the total survivability index, while the quality of the system maneuverability could be Q = 0.80 compared to maneuverability of other systems in the category. The weighting factors were derived by using a Delphi ranking technique with a group of military subject matter experts. The WEI scores for each weapon system were then normalized to the WEI value of the category representative and produced sets of scores that compared all the weapons in each category.

WUV methodology. The WUV methodology then combined the WEI scores, the unit's weapon counts, and category weights to produce a weighted unit value for a combat unit. Assuming ten system categories, the basic formula to develop a WUV score for each unit would be:

$$\text{WUV} = \sum_{a=1}^{10} (CW)_a \left[\sum_{n=1}^{m} C_n \, (WEI)_a \right]$$

Where:

WUV = weighted unit value.
C_n = number of combat effective weapons of a unit by type weapon.
$(WEI)_n$ = weapon effectiveness index.
$(CW)_a$ = category weight of weapon category.
a = integer representing weapon category (1-10).
n = integer representing type of weapons.
m = total number of weapon types within weapon category.

Although this approach was a significant achievement in computing the values of lethal systems, one of the shortcomings of the WEI/WUV involved reliance on subjective judgments regarding weightings and input values. Another issue, common to all approaches that add system values, is whether summation is appropriate. Summation tends to assume independent contributions whereas in the real world, commanders strive to achieve synergy by employing weapons and units in combinations. If a weapon's features are combined by addition, a high enough value or weight on one characteristic compensates for poor scores on the others. In reality, both characteristics may be necessary for success. Another perceived shortcoming is the potential for misinterpretation of the numbers outside of their intended use for examining combat outcomes to inform decisions about force structure and force design. For example, General Sullivan is cited above for stating that the M1A2 tank is 18% better than the M1A1. In the context of combat operations, that 18% may make the difference between victory and defeat for an engaged force. However, if taken out of that operational context and placed into a strictly budgetary context, if the cost of the M1A2 is more than 18% greater than the cost of the M1A1, the budget analyst will ask if it is "cost-effective" to buy it. Although the Sullivan example was not based on WEI/WUV scores, it illustrates the potential for difficulties with this approach. The reader should note that WEI/WUV scores have been out of favor in the U.S. Army since the late 1980s because of some of the difficulties cited above.

Other related methods

The research team examined a variety of methods described below, each with strengths and limitations. Each method has some utility in the "real world" to inform operational force allocation and/or course of action decisions and force structure and acquisition decisions.

Unit readiness process. This is an approach that measures unit readiness. It involves measuring troop strength and training, equipment on-hand, and equipment availability for operations. Each measure is placed within a range of readiness, called C-ratings. Thus a unit that is C-1 is fully mission capable, while units at C-2 or lower require some remedy (personnel, equipment, or training) to be fully ready. The approach is described in Army Regulation (AR) 220-1, Unit Status Reporting, 19 December 2006. For Army units, the Unit Status Reporting (USR) system enables the commanders of reporting organizations to uniformly determine and accurately report an overall level indicating the ability of their units to accomplish the wartime missions for which the units are organized or designed via the C-level. When applicable, the system also captures the ability of units to accomplish currently assigned or directed missions via the percent effective (PCTEF) level. For each of these status-level assessments (C-level and PCTEF-level), the USR system indicates the degree to which a unit has achieved prescribed levels of fill for personnel and equipment, the operational readiness status of available equipment, and the training proficiency status of the unit. This approach appears to have potential for use because the military is familiar with it and the overarching Global Status of Resources and Training System (GSORTS) database uses this information to maintain an overall force status for use by the Chairman, Joint Chiefs of Staff. The principal drawback of this approach is that it does not directly compare the effectiveness of the reporting force relative to opposing forces.

Strength based on percent remaining of "pacing items". This is an approach related to the Unit Status Report process described above. The Unit Status Report makes use of "pacing items" that are certain systems critical to the unit's ability to accomplish its designated mission. Normally there are only one or two pacing items per unit, but not more than four. If a unit is low on "pacing items" that drives the unit readiness rating to the level of availability of the pacing item. This approach supports good unit decisions but is difficult to aggregate for higher echelons. At higher echelons, instead of combining or adding "pacing items" across the force, the higher echelon may have to base decisions on the number of subordinate units that are mission-capable with respect to each subordinate unit's "pacing items".

Red-Amber-Green ratings. This approach is based on a calculated strength value but still relies on a subjective evaluation of the range for a particular color. For example, remaining strength between 90% and 100% may be Green. Amber may be 75% to 89%, and Red is any strength less than 75%. This may not take into account the specific mission of the unit and thus lead to less than optimal decisions.

“School house” unclassified unit combat power weights. An example is the relative combat power analysis that is taught at the U.S. Army Command and General Staff College. The instruction provides some nominal values for different types of units (armor, artillery, infantry, etc., and provides some illustrative examples of the use of relative-force ratios to help identify possible courses of action. The values used are adequate for teaching purposes, and have some value in generating thought with regard to potential courses of action for actual operations. They do not appear to be adequate for combat development capability assessments or for decision-making in other than traditional combat operations. In one version of the student text, the commentary states,

> *“He (the planner) would be able to use this information (relative force ratio) when he begins developing a scheme of maneuver. If he identifies a ratio closer to one of the other planning ratios, he could draw other conclusions indicating another type of possible operation. This step provides the planner with a notion of "what to"; not "how to." There is no direct relationship between force ratios and attrition or advance rates. Relative-force ratios do not necessarily indicate the chance for success.”* (17)

Anti-potential Potential and related formulations. This approach relies on assessment of system versus system attrition rate but is very situation dependent. For example, for Blue unit X, it defines X’s lethality recursively by relating X's values to the rate at which its weapons destroy Red unit Y's valued systems, the latter being defined in turn by the rate at which they destroy X's value. It leads to calculating eigenvalues of matrices involving the attrition rates of each weapon versus each of the opponent's. One commentator points out two problems. The first is that this approach can be used only in contexts when attrition is linear and when the allocations of weapons to types of targets are fixed throughout the combat. The second difficulty is that the values of the weapons are defined without reference to the value of the benefits to the possessors. Again, no functional value other than lethality is included. (18)

Options considered.

After preliminary examination of the approaches described above, the research team developed candidate approaches for further consideration. In addition to the constraints listed above, the options had to be able to address the mission-specific value to the commander of non-kinetic capabilities. Each option shown below meets that criterion via a combination of methods.

Option 1 - Improve method for developing firepower scores and <u>strength values</u>.
- Use dynamic calculation based on simulation results, and/or
- Introduce additional factors for assessing functionally- specialized systems or multi-function systems.

Option 2 – Use a new combination method.
- Use a unit readiness approach, combined with Joint function capability assessment with designation of “pacing items”. “Pacing items” are systems that are key to the unit’s overall combat strength, central to the unit’s ability to perform its doctrinal mission, but

may vary as a function of unit type. Typically one or two, but no more than 4 "pacing items" are designated for a unit.

Consideration of options:

Option 1 - Improve method for developing firepower scores and strength values.

Dynamic calculation. The following are examples of how simulation results could be used to provide combat power values (by joint function) for subsequent simulation runs. The method assumes that either traditional firepower scores or a weighted value has been placed on the lethal systems of both Blue and Red forces.

Fire Support measure. The combat power value of an artillery piece is based on the value of the systems it killed in a simulation run.

$$\text{Indirect Fire Lethality}_k = \sum (\text{number enemy killed}_j * \text{value}_j) / (\text{\# of artillery systems}_k)$$

Sustainment Measure. The combat power values of ammunition trucks are derived from the value of the ammunition transported, which is in turn based on value of the targets killed by that ammunition type. The CPV of a fuel truck is set to that of a similar size ammo truck. This results in somewhat higher values for trucks than used traditionally. The value of a maintenance team is derived from the value of systems repaired. For ease of calculation, all repair team types are averaged.

Intelligence Measure. Sensors and intelligence fusion systems derive value from the targets they nominate and the value of the information they place on the Common Operating Picture (COP) for a unit. This value may be hard to derive depending on the resolution and recording of the data going into fusion and information update algorithms.

Using a simulation to calculate its own input requires additional model runs to generate data, which in turn could cause changes in results that require more runs to achieve a stable solution. The values calculated are only useful in that one particular scenario. When comparing two systems, variances in employment may cause larger differences in CPV than system capabilities. If there is a significant counter battery battle, then the value of each side's artillery will increase proportionally to the value of what was killed, yielding the nonlinear results seen in the anti-potential potential approach discussed above.

A variation of this approach was proposed by an analyst at the Unit of Action Mounted Battle Lab in 2004 under the title of Correlation of Forces. (19) The Correlation of Forces equation proposed was:

$$\text{COF} = \frac{\left[\sum_{j=1}^{m} \left(\sum_{i=1}^{n} \frac{P_{ij}}{T_i} \times W_i \right) \times S_j \middle| \text{BLUFOR} \right]}{\left[\sum_{j=1}^{m} \left(\sum_{i=1}^{n} \frac{P_{ij}}{T_i} \times W_i \right) \times S_j \middle| \text{OPFOR} \right]}$$

Where:

COF = Correlation of Forces
P = Performance of metric i for system j.
T = Performance of force for metric i.
W = Weighting factor for metric i.
S = Number of system j in force.
m = Index of system j.
n = Index of metric i.

The methodology proposed using nine force level metrics to cover lethality, survivability, and acquisition performance of both opposing and friendly force systems. This methodology would require all models to run baseline runs to formulate initial COF values. Correlations developed using the Janus model are different from correlations using Battle Laboratory Collaborative Simulation Environment (BLCSE) federation models. This is a factor of model fidelity, entity representation, and other functional representation limitations of the model themselves.

In summary, the pros and cons of this type of dynamic approach to improving the combat power values are:

Pro: - Accounts for multiple factors and the complexity of combat system interactions.
Con: - Requires many simulation runs (time and resources),
- Difficult to access run library for appropriate value. Research indicated that accessing the appropriate value from a library may require indexing based on over a dozen parameters associated with weather, terrain, friendly force status, and enemy force status.
- Emphasizes the kinetic (lethal) capability over the non-kinetic enabling capabilities.

Static calculation. Alternatively, the analyst could attempt to create a score for each military system based on its static design characteristics or system performance relative to a particular joint function capability. Simply stated, the analyst would add factors to the calculation in support of each joint function capability and calculate a new score or value for each system with respect to that factor. This differs from the dynamic approach in that combat simulation runs are not required to generate the data. However, for certain system performance metrics, this approach may require the use of system performance models and simulations such as those used by Army Materiel Systems Analysis Activity to develop reliability, mobility, or other performance metrics. The added benefit of this approach is that it allows measurement of the relative value of each system for those functions which are non-kinetic or inherently non-lethal, such as sustainment, command and control, and intelligence. These non-lethal functions may be very important in stability operations, irregular warfare or weapons of mass destruction situations. Figure 2 below illustrates the linkage between the functions and their integration through leadership.

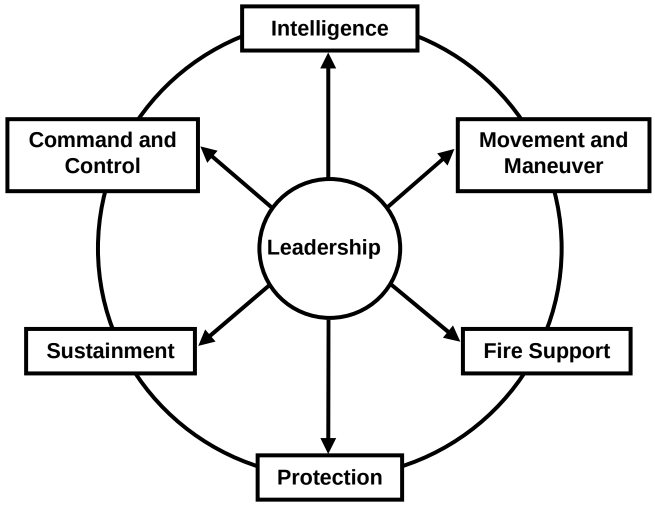

Figure 2. Joint functions integrated by leadership.

Examples of this approach for certain functions might include the following:

Fires support measure. Whereas in the dynamic value calculation, the value of a fire support system (e.g., artillery piece) could be based on the value of what it killed in a simulation run, in a static value approach, the value of a fire support system could contain the following components:

- Tested lethality (function of accuracy and kill mechanism).
  - --Single shot probability of kill for a precision weapon against a typical target, or
  - --Damage from an area effects weapon (blast or fragmentation) against a typical target based on lethal area calculation.
- Designed or tested rate of fire.
- Designed or tested range of weapon.
- Number of rounds/bombs carried on board.

Sustainment measure. Whereas in the dynamic value calculation, the value of sustainment might be derived from the value or lethality of the supplies a system transported or the value of systems it repaired, in the static value approach, the following aspects might be measured:

- System reliability measures:
  - --Mean time between failures.
  - --Mean miles between failures.
  - --Mean time to repair.
- Transport capacity measures:
  - --Weight and volume.
  - --Speed of transport.
  - --Mean time to load and unload full capacity.
- Round trip traveling range of system without refueling.
- Recovery capability (what weight, size of incapacitated system can be recovered by index system).

In summary, the pros and cons of this static functional value approach to improving the combat power values are:

Pro: - Accounts for functional capability to include non-lethal functions.
Con: - Requires classification of system by contribution to joint function.
- Presents difficulty of determining appropriate metric to compare functional value across the systems.

Option 2: Combine unit readiness and elements of combat power by joint function. This option combines the unit readiness ratings described above with the use of pacing items focused on the joint function capability.

Unit readiness accounts for personnel strength as a percent of authorized strength, system strength as a percent of authorized system strength, system availability (accounts for maintenance and combat damage), and training level (accounts for differences in application of systems and unit tactics). The lowest value drives the overall unit strength. Warfighters understand and use AR 220-1 USR and the GSORTS. Measuring personnel status enables accounting for personnel availability that is important in stability operations, irregular warfare and weapons of mass destruction (WMD) environments.

Combining unit readiness with the joint function assessment with “pacing” items enables consideration of combat enablers and enables combat simulation adaptation and application in stability operations, irregular warfare, and weapons of mass destruction scenarios. This method enables the model/simulation to more faithfully represent a commander’s multi-dimensional decision-making process. It also enables better representation of perception and ambiguity. For example, perception or ambiguity might result from a time-delay for reporting status to higher headquarters or delays in getting information from higher headquarters to subordinate units. It also requires more thoughtful “decision rules” for decision-making. For example, what functions are necessary to accomplish the mission in a particular situation, and what are the thresholds for “pacing items” that cause a unit to lack capability for mission accomplishment in a situation?

The concept of using pacing items to make decisions is not new, but the research showed that it is in use only in brigade and below simulations. We found no examples of this technique used in aggregated higher echelon simulations.

The pros and cons of the components of this approach are summarized below.

Unit readiness component.

Pro:
- Used and understood by warfighters.
- Accounts for personnel status.
- Accounts for differences in training levels of friendly and threat “regulars”, militia, and insurgents.
- Determines unit’s strength based on lowest value among personnel, equipment, or training.

Con:
- Requires accounting for personnel.
- Requires assessing unit training level (somewhat subjective).
- Requires more comprehensive decision rules in combat simulations.

Joint function component.

Pro: - Army already uses "pacing" items in USR.
- Can be linked easily to USR approach.
- Can apply perception or ambiguity to strengths.

Con: - Requires classification of system by contribution to joint function.
- Requires designation of "pacing" item(s) for one or more joint functions.
- Requires more thoughtful "decision rules".

Proposed new method.

The method proposed by the research team is option 2, the method that combines unit readiness with assessment of joint functions using "pacing" items. It appears to have great promise because it facilitates consideration of combat enablers, and presents opportunities for application in areas of stability operations, irregular warfare, and weapons of mass destruction scenarios. Because components of the system are familiar to warfighters and unit commanders, this may also provide some potential for assisting commanders in making decisions during course of action analysis and planning for actual operations. The general formulation of the new method for use in decision-making in models and simulations is shown below.

General formulation of new method for use in decision-making:

Given blue unit of type T_{Blue} in mission status M and environment S, decision whether or not to execute the k^{th} set of n_k actions $A_k = \{a_1, ..., a_{n_k}\}$, where $k \in [1, p]$ and where m red units are within a specified distance D from blue unit is based on criteria expressed as:

If $Min\{P_{Blue}, E_{Blue}\} \geq X_1(T_{Blue}, a_1, ..., a_{n_k})$ and $w_i(T_{Blue}) \geq W_i(T_{Blue}, a_1, ..., a_{n_k})$, $\forall i \in [1,6]$ and $Min\{P_{j\ Red}, E_{j\ Red}\} \leq X_{2j}(T_{j\ Red})$, $\forall j \in [1, ..., m]$

Then execute actions A_k. Else if $k \neq p$, check decision criteria for A_{k+1}.

Where P = Percent personnel remaining,

E = Percent equipment remaining,

X_1= Threshold variable,

w_i = Level of the i^{th} Function for blue unit type T_{Blue} based on count of pacing items,

W_i = Threshold variable for the i^{th} Function,

X_2 = Threshold variable,

$T_{j\ Red}$ = Type of the j^{th} red unit.

The following describes the formula shown above:
For a blue unit of type T (e.g. Armor) in mission status M (e.g. attack) and environment S (e.g. desert, rolling), then criteria to execute a set of actions A_k(e.g. continue to attack, call for additional artillery support, request close air support, initiate call for fuel resupply) is:
If the minimum percent of personnel remaining or equipment remaining is greater than or equal to the threshold level for each of the actions in set A1 and the percent remaining of the pacing item(s) for each joint function is greater than or equal to threshold level W_i , and the minimum of the perceived percent personnel remaining or perceived percent of equipment remaining for each Red unit type j is less than the criteria threshold for Red unit type j, then execute actions A_k.
Else if k not equal to k_p, then check criteria for set of actions A_{k+1}

In a stability operations environment, the same decision formulation could be used for a set of actions that included allocation of construction engineers, water purification, fuel or food distribution, transport of humanitarian assistance materiels, and so forth.

Summary.

This research effort examined and compared a variety of methods. The proposed method reduces the subjectivity of system weighting and firepower factors. It uses commonly understood Unit Readiness and "pacing item" techniques. It considers the importance of joint functions, and enables improved representation of a unit's capabilities for stability operations, irregular warfare, and weapons of mass destruction situations. By presenting a recommended decision formulation that accommodates these aspects, it enhances the potential application of new models and simulations that are communications-enabled, perception-driven, and commander-focused, such as Advanced Warfighting Simulation. Finally, because the components of the proposed method are familiar to military commanders and staffs, the decision formulation may have potential to inform course of action analysis and planning for actual operations.

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